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ABUNDANCE, DISTRIBUTION AND DIVERSITY OF AQUATIC MACROINVERTEBRATES ON THE NORTH SLOPE OF THE ARCTIC NATIONAL WILDLIFE REFUGE, 1982 AND 1983

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ABSTRACT

Quantitative aquatic macroinvertebrate samples were collected from 46 sites in the vicinity of 1002c Study Area, Arctic National Wildlife Refuge, during the summers of 1982 and 1983. Density, biomass, number of taxa, diversity (H') and evenness (J') values were determined for macroinvertebrate communities from all stations. Mean values were compared for tundra, spring, and mountain stream types. Density of invertebrates ranged from 11 organisms/m^2 to 15,555 organisms/m^2. Mean density increased by nearly an order of magnitude between mountain and tundra streams and between tundra and spring streams. Species composition was dominated by taxa of Orthocladiinae, Simuliidae, Oligochaeta, and Baetidae. The majority of the taxa collected were representative of the collector - gatherer functional group. The scarcity of other functional groups was reflected in the generally low diversity (H') values found in the study area. Highest diversity values were found in tundra streams. Low diversity values were found at spring stream sites, and were attributed to the high redundancy of chironomids in the invertebrate samples at these sites. Significant positive correlations ($P < 0.01$, $r \neq 0$) were found between density and biomass of organisms with alkalinity and conductivity values.

INTRODUCTION

Section 1002c of the Alaska National Interest Lands Conservation Act (ANILCA) made provisions for an assessment of fish and wildlife habitat of the coastal plain of the Arctic National Wildlife Refuge. During 1981 - 1983, the Fairbanks Fishery Resources Station has conducted studies in accordance with the fishery portion of the mandate. Aquatic macroinvertebrates were sampled, in addition to collection of fish distribution, abundance and life history data.

There is very little information published pertaining to aquatic macroinvertebrate communities in Alaskan arctic streams. Slack et al. (1979) compared differences in macroinvertebrate communities between a north and south-flowing stream in the Brooks Range of Alaska. Craig and McCart (1975) sampled invertebrate populations in stream drainages between Prudhoe Bay and the Mackenzie Delta. They reported standing crop information, and taxonomic information primarily to order for most taxa and to family for Dipterans.

Aquatic macroinvertebrates are important in the food chains for most fish species found in streams draining the North Slope. Their abundance and distribution can be useful in biological classification of arctic waters and aid in understanding the distribution of fishes in these waters. They are also useful in monitoring environmental perturbations, and are generally more sensitive to environmental changes than fish. Benthic invertebrate communities exhibit a diverse fauna, inhabiting many different microhabitats, are not capable of much avoidance to sampling techniques and exhibit varying levels of tolerance to pollution and other perturbations.

This report provides baseline data on aquatic macroinvertebrate populations for streams draining the 1002c Study Area, and may serve as a basis of comparison in the event of resource development within the study area.

METHODS AND MATERIALS

USGS, 1:63,360 quadrangle maps were used to determine stream order, channel character, and gradient of stream study area reaches. Stream order was determined following the method of Strahler (1957). Gradients were calculated from 50 and 100 foot contour lines on the maps. Stream reaches were assigned to one of the four categories: straight, irregular, braided, or meandering (Smith and Glesne, 1982). Percent pool, riffle, shallows and substrate particle size were estimated by observation of a 100 meter section of the stream at each study site.

Water chemistry parameters; pH, total hardness, total alkalinity, and dissolved oxygen, were measured using a Model FF-1 Hach water chemistry kit. Conductivity was measured in micromhos per centimeter using a Hach Model 17250 Mini Conductivity meter.

Discharge was calculated using the following formula:

$$Q = W\ D\ V$$

Q = Discharge
W = Width of Wetted Perimeter
D = Mean Depth
V = Mean Velocity

Depth was measured to the nearest tenth of a foot using a standard wading rod. Velocity was measured at approximately 0.6 the water depth using a Marsh - McBirney Model 201 current meter.

Benthic samples were collected between June and September 1982 and between July and September 1983. Most of the samples were collected during July and early August of both years. Three replicate samples were collected at each station using a 1024 micron Surber sampler. All samples were collected in stream riffles. Samples were placed in Whirl Pak bags and preserved with a 5 to 10% formalin solution.

In the lab, a sample was first washed through a Tyler Standard 0.147 mm screen to remove the formalin and silt, then transfered to a large tray. Small subsamples were then transfered to a smaller white tray with grid lines drawn on the bottom to assist in processing the sample. The organisms were then placed in small, labeled vials and preserved with 70% isopropyl alcohol. Samples with large amounts of moss were washed and dissected thoroughly to dislodge clinging organisms.

Organisms were identified to genera where possible, using a Bausch and Lomb 1-7x dissecting microscope. Chironomid larvae were first sorted into look alike groups under the dissecting scope. Then representatives from each group were mounted on 1 X 3 inch slides, using CMCP-10 mounting media, and then identified to subfamily at 100X and 400X on a Nikon microscope. Blotted wet weights for all taxonomic groups were obtained using a Sartorius analytical balance. Wet weights and counts, for each taxa were then recorded. Taxonomic references used for invertebrate identification included Merrit and Cummins (1978), Usinger (1973), Pennak (1978), Wiggins (1978), Edmunds et. al. (1976), Johannsen (1969), Beck (1976), and Stewart (in press).

Aquatic macroinvertebrate diversity (H') was calculated according to the following equation:

$$H' = -\sum (p_i \log_2 p_i)$$

where p_i was the proportion by number of the community belonging to the $_i$th species (Pielou, 1975).

This index was originally proposed (Shannon and Weaver, 1949) as a measure of the information content of a code. Diversity values depend on both species richness (the number of species) and evennness of representation of species within the community. Evenness (J') was calculated as:

$$J' = \frac{H'}{\log_2 S}$$

where s equals the species richness and H' equals diversity (Pielou, 1975).

Evenness values range from 0 to 1 with 1 representing the greatest evenness of representation of species within a community. A predominance of one species or a few species in a community would be represented by J' close to 0.

The mean, standard deviation, standard error, and sampling precision were calculated for biomass, density, diversity and eveness from each set of samples from each station. Density (number of organisms/sample) exhibited a negative binominal distribution therefore, the log (x + 1) transformation was used before performing statistical analysis (Elliot, 1971). Least square regressions and scatter diagrams were generated to determine relationships between physical parameters and macroinvertebrate densities, biomass, diversity and evenness values. Significance levels based on the correlation coefficient were determined using the tables found in Zar (1974).

STUDY AREA

The study area, is approximately 630,000 hectares, and was bounded on the west by the Canning River, on the east by the Aichilik River, on the south by the Brooks Range, and on the north by the Beaufort Sea (Figure 1).

The area may be conveniently classified into zones or provinces after Wahrhoftig (1965) who recognizes an Arctic Coastal Plain, Arctic Foothills, and Arctic Mountain Province.

Within the study area the coastal plain is fairly narrow (15-25 km) and less distinct to the extreme east. The area is mostly poorly drained, with relatively few lakes compared to more westerly areas of the coastal plain. The shore is generally only 1-10 ft. above the ocean. The permafrost table was reported to be only 1/2-4 feet below the surface and quaternary marine sediments, as well as tertiary sedimentary deposits, underlie the area (Wahrhoftig 1965). The soil is neutral to slightly alkaline and commonly has a 8-12 cm layer of organic material overlying loam. The 600 foot contour line is often used to separate the coastal plain from the foothills.

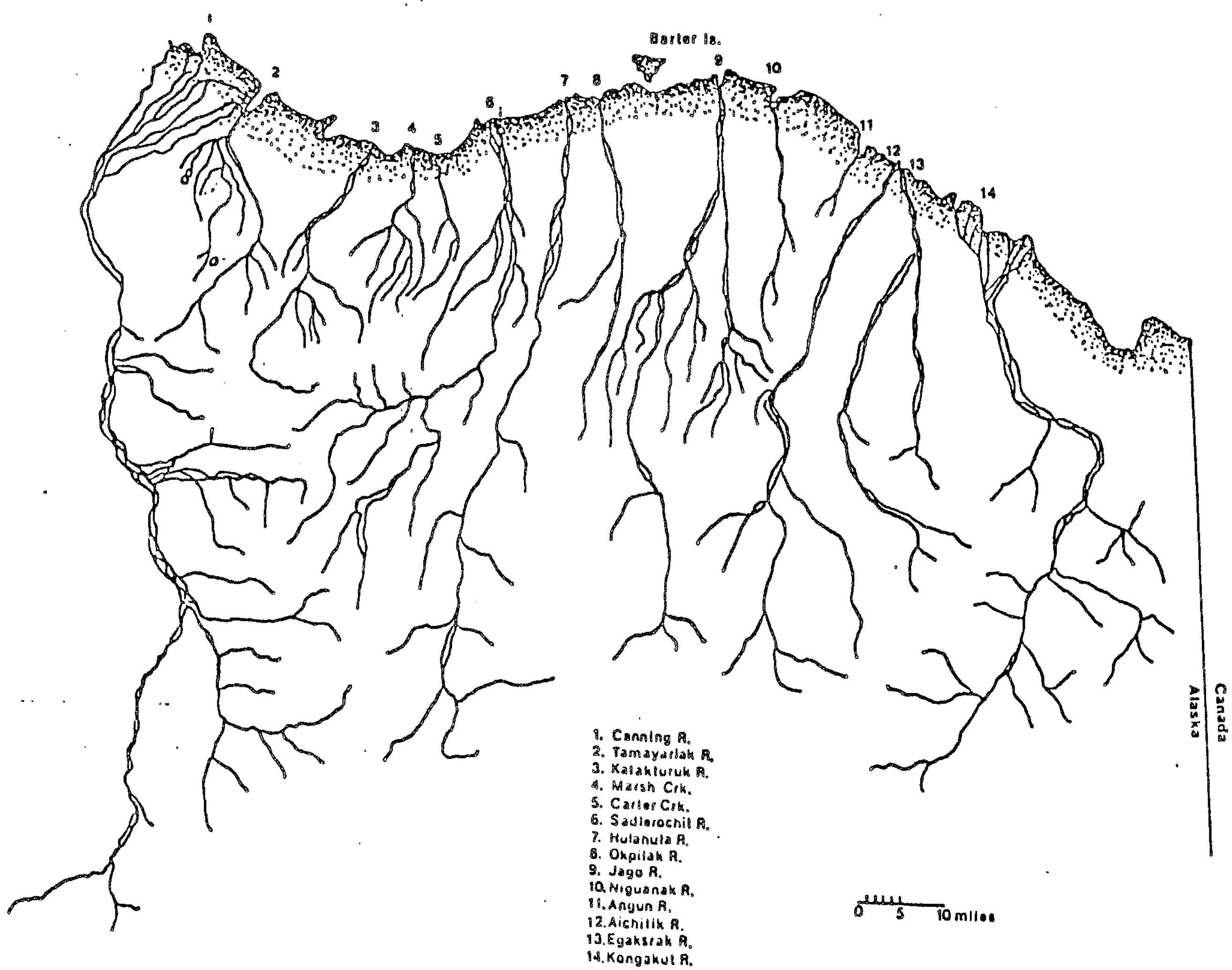


Figure 1. Major drainages within the 1002c Study Area.

The foothills comprise the largest zone within the study area (44%). Rolling plateaus and low linear mountains (to 1200 feet), with east-trending mountains characterize the area. The dominant vegetation consists of a Moist Tussock, Sedge-Dwarf Shrub, Tundra complex. Dark colored mineral soils (mollisols) which are neutral to slightly alkaline in reaction tend to predominate. Devonian to Cretaceous age sedimentary rocks underlie most of the foothills. When exposed these are tightly folded and overthrust to the north (Warhoftig 1965). The southern margin was glaciated during the Pleistocene, and glacial debris covers portions near the mountains (Craig and McCart 1974).

The Arctic mountain province makes up a smaller portion of the study area. This area includes the Shublik and Sadlerochit Mountains in the southwest part of the study area to the Romanzoff Mountains in the extreme east. The extreme southern edge of the study area is dominated by weather resistant metasedimentary quartzites, phyllites, schists, and argillites. Immediately north is a narrow east-west belt of the Lisbourne formation which consists of Mississippian limestone and dolomites (Hobbie 1962). The Shublik and Sadlerochit Mountains are underlain by sandstone, siltstone, and shales. The vegetation ranges from alpine tundra and barren ground, in the Sadlerochit and Shublik Mountains, to vegetation similar to the foothill province. Valley and piedmont glaciers advanced throughout the area during the early Pleistocene to the Quaternary ages.

The climate tends to parallel the zones described above. Foggy, often windy and rainy weather with cooler temperatures dominate the coastal areas, while clearer, warmer, and drier weather is generally found in the foothills during the summer. Rainfall in the area is slight (less than 8 inches). Snowcover is scanty in the winter and is drifted into hard banks by prevailing easterly or westerly winds. Photoperiods are extreme. Depending on the location and latitude, darkness may persist for as long as 83 days during winter and continuous daylight may last for 61 days during the summer (Hobbie 1962).

The principle drainages within the study area include: the Canning River, Tamayariak River, Katakturuk River, Marsh Creek, Carter Creek, Sadlerochit River, Hulahula River, Okpilak River, Jago River, Niguanak River, Angun River, and Aichilik River (Figures 1-7).

The dynamic character of streams defies any absolute classification of them, but in general they tend to follow the physiographic provinces just described above. This is based on the premise that streams reflect the geology, soils, and vegetation they originated from. Craig and McCart (1974), and more recently Harper (1981) have classified arctic streams according to this principle. They identified mountain streams, spring-fed streams, glacier-fed streams, and tundra (lowland) streams. Streams of these types are found throughout the study area. Unless otherwise noted the following is a summary of these two reports.

Mountain streams often exhibit low stream order and high gradient. The water originates as surface runoff or from springs. Flow regimes for these types of streams are highly variable compared to spring or tundra stream. Eighty percent or more of the annual flow may issue during the spring thaw. These streams often dry up during the summer. Riparian (bank-side)

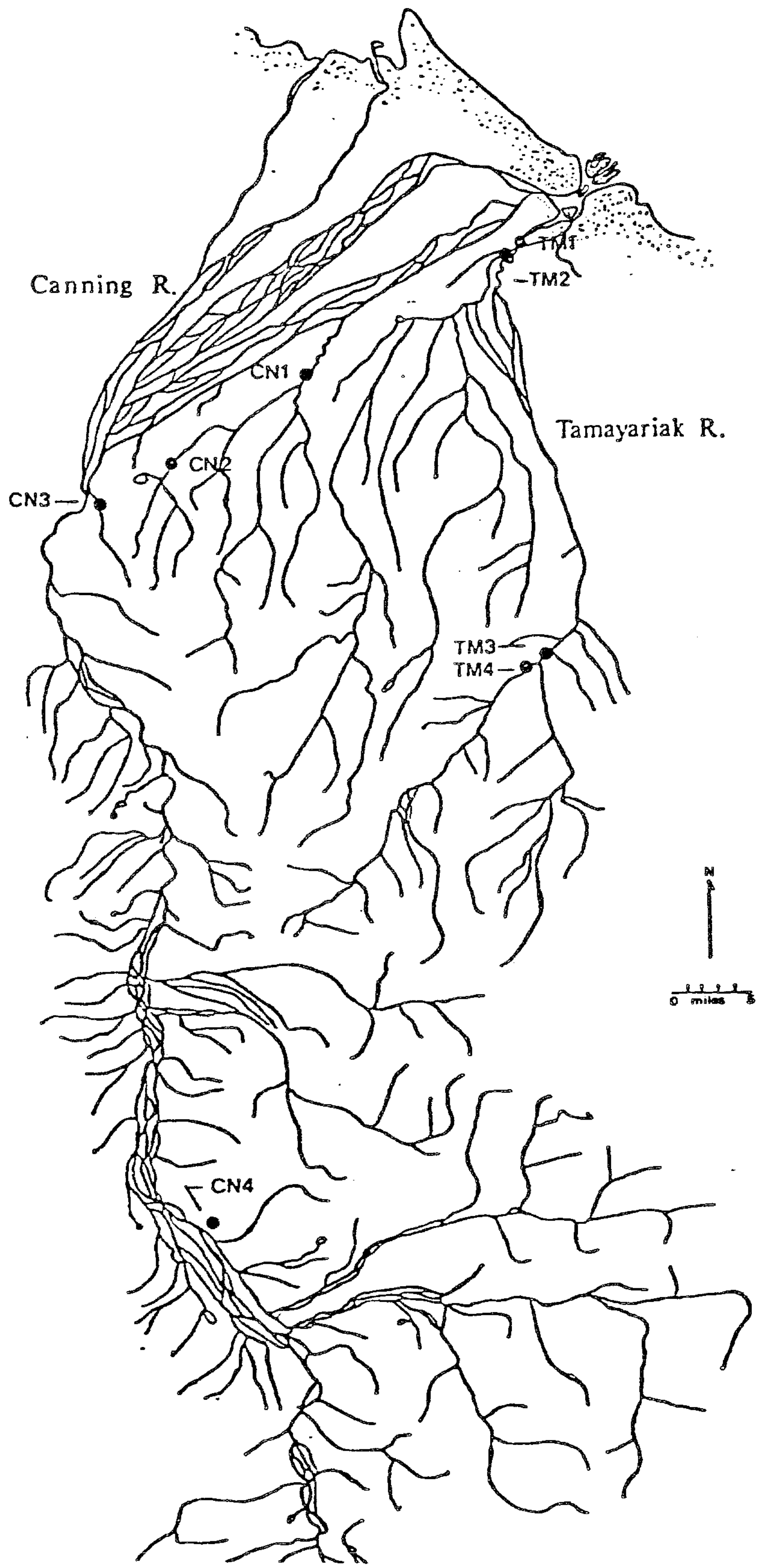


Figure 2. Macroinvertebrate sample locations on the Canning and Tamayariak Rivers for 1982-1983. (Not all of the Canning River drainage is shown.)

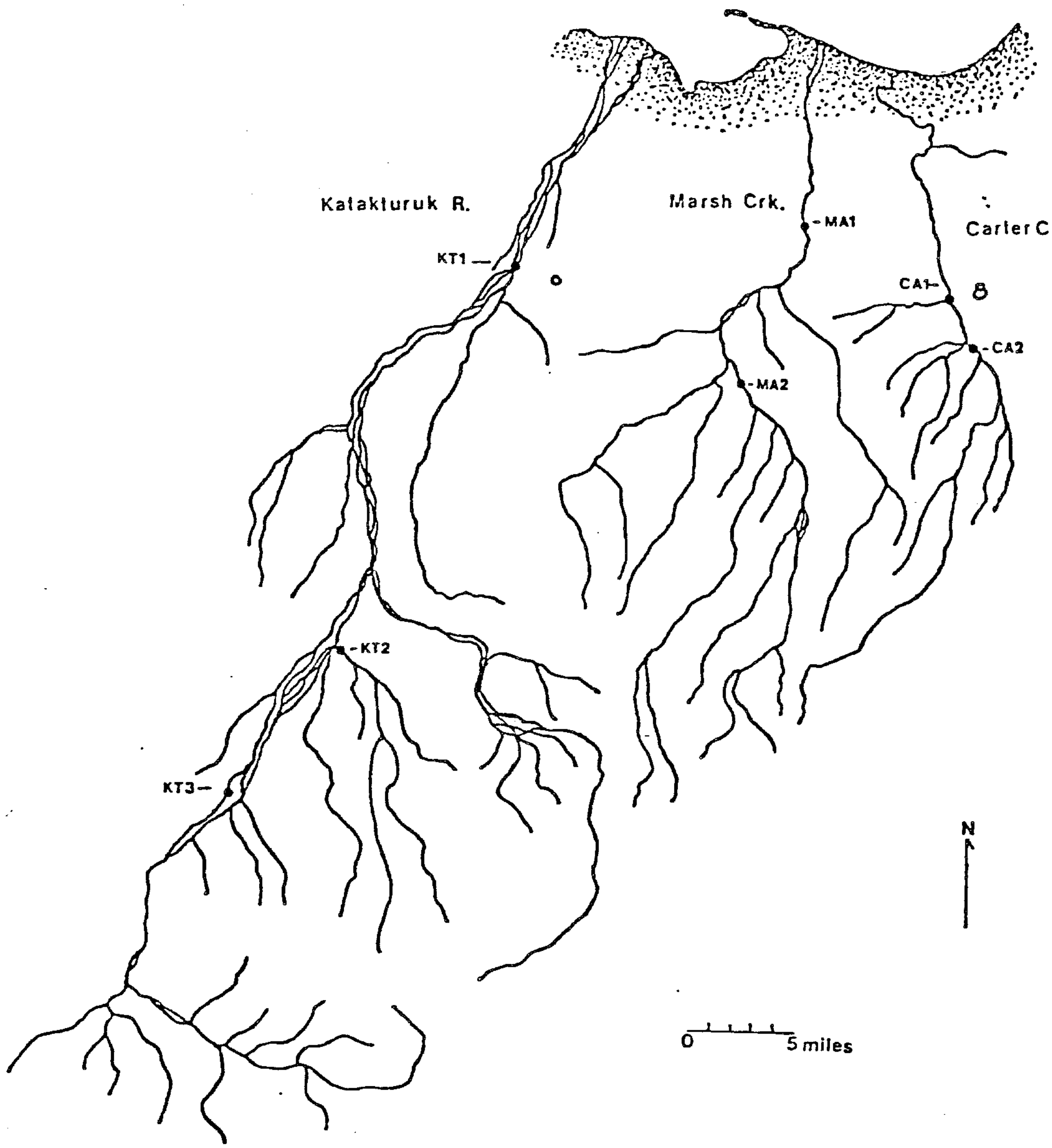


Figure 3. Macroinvertebrate sample locations on the Katakturuk River, Marsh Creek, and Carter Creek for 1982-1983.

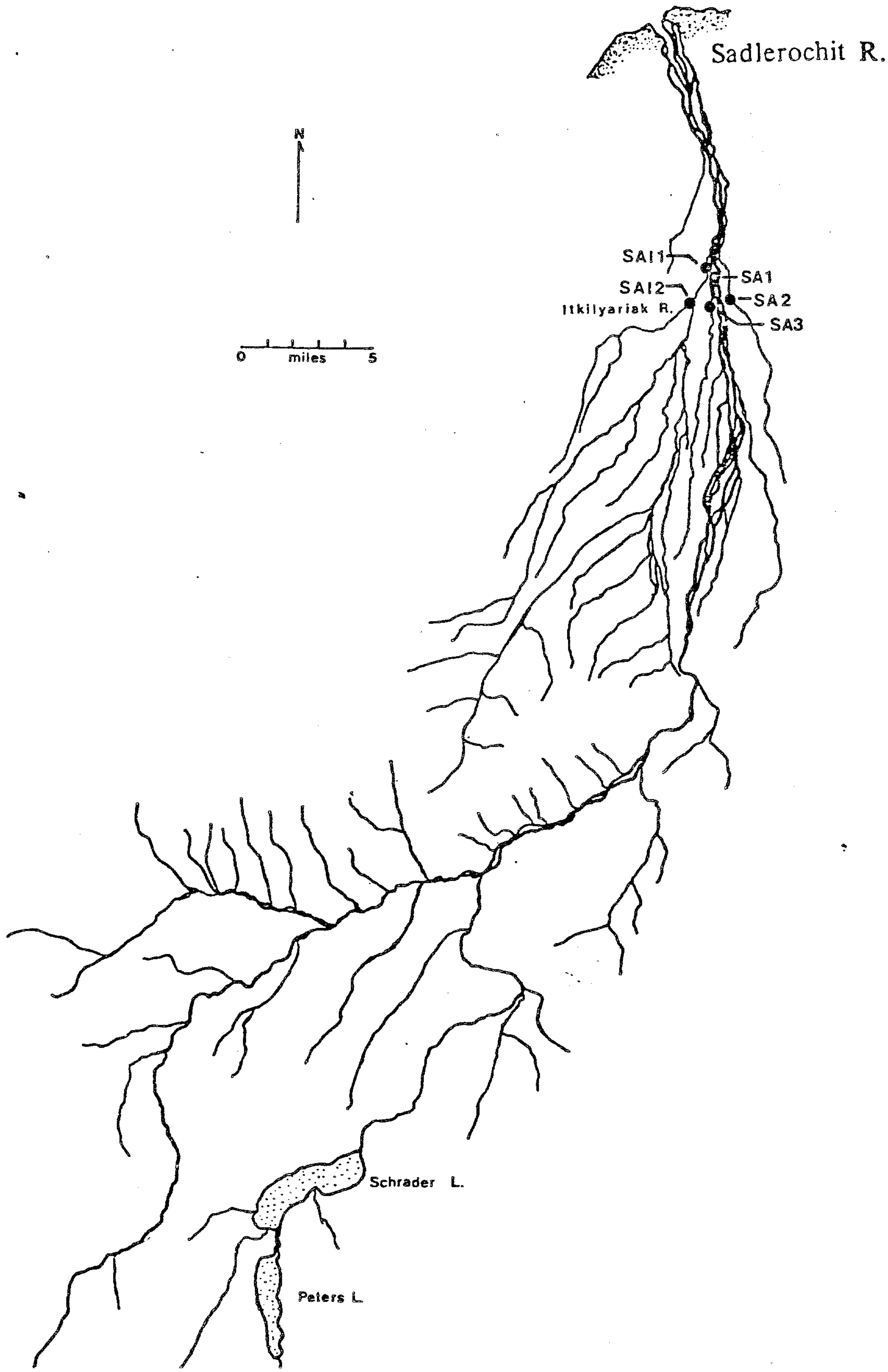


Figure 4. Macroinvertebrate sample locations on the Itkilyariak and Sadlerochit Rivers for 1982-1983. (Not all of the Sadlerochit River drainage is shown.)

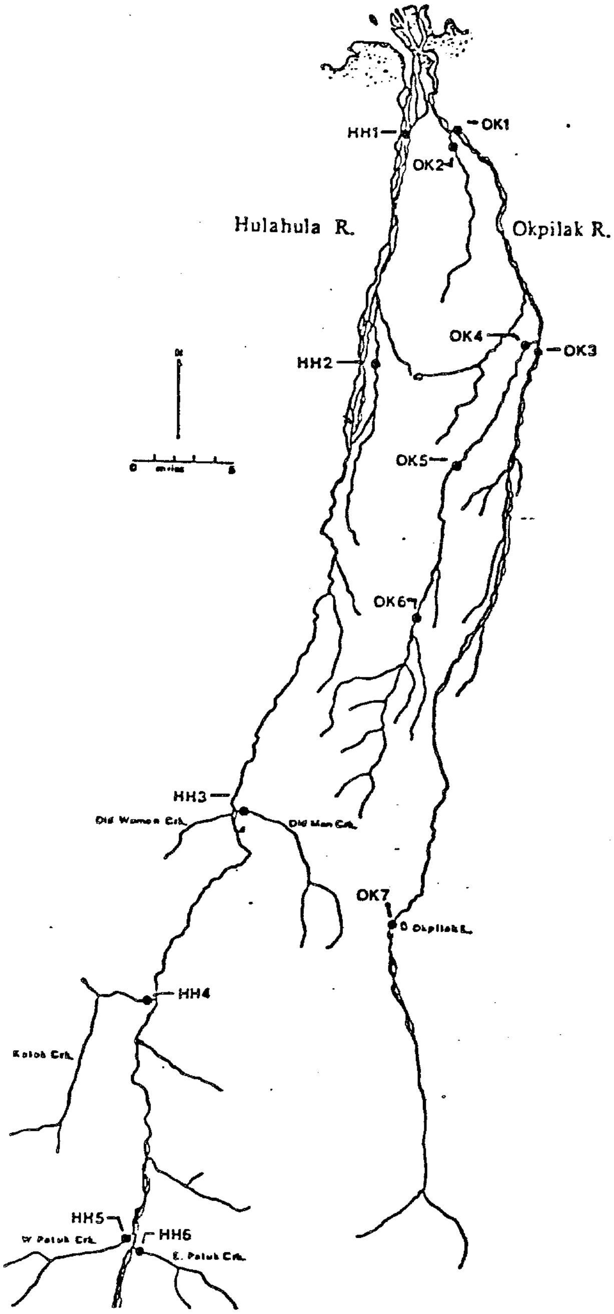


Figure 5. Macroinvertebrate sample locations on the Hulahula and Okpilak Rivers for 1982-1983. (Not all of the Hulahula River drainage is shown.)

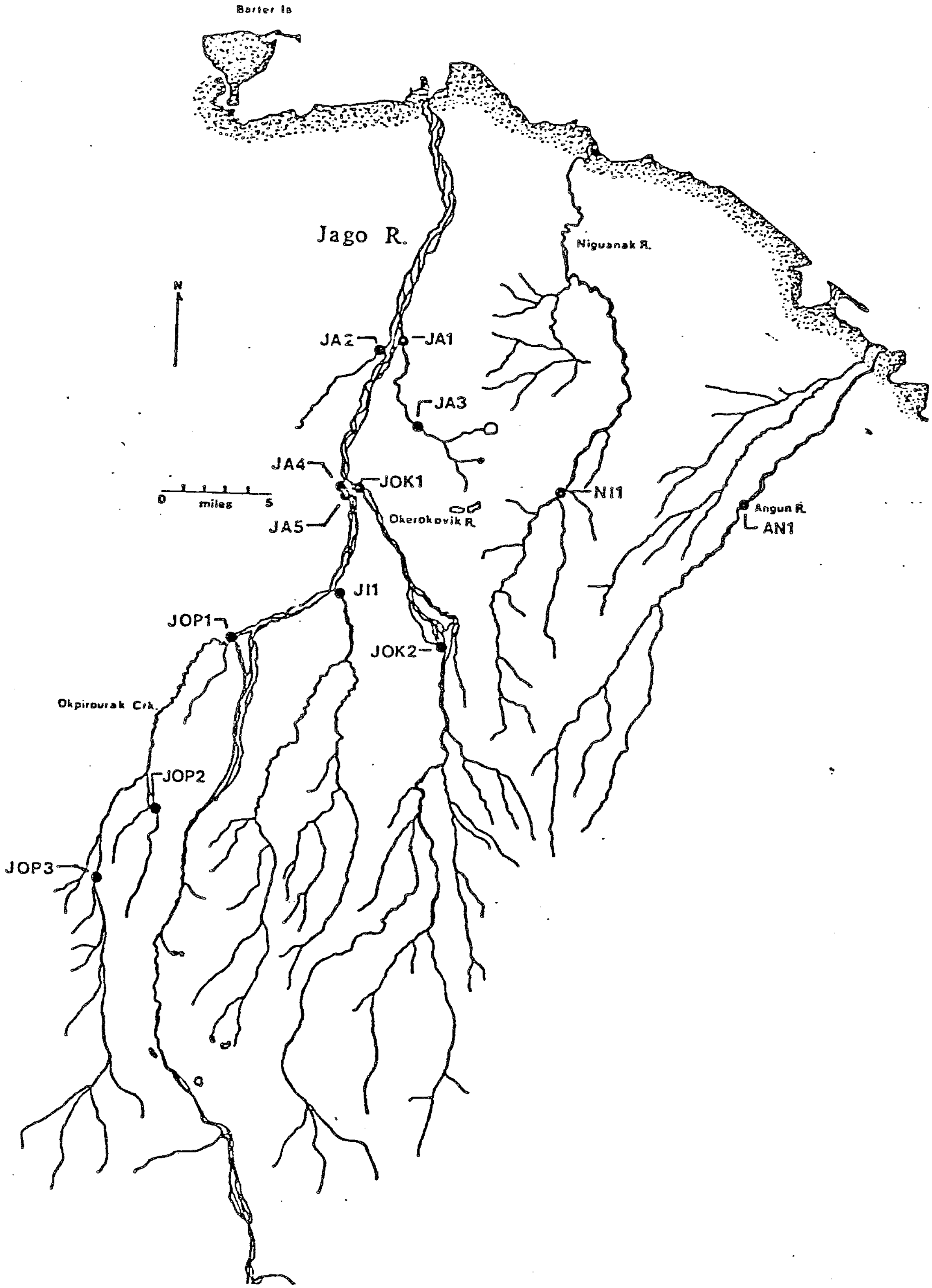


Figure 6. Macroinvertebrate sample locations on the Jago, Niguanak and Angun Rivers for 1982-1983. (Not all of the Jago River drainage is shown.)

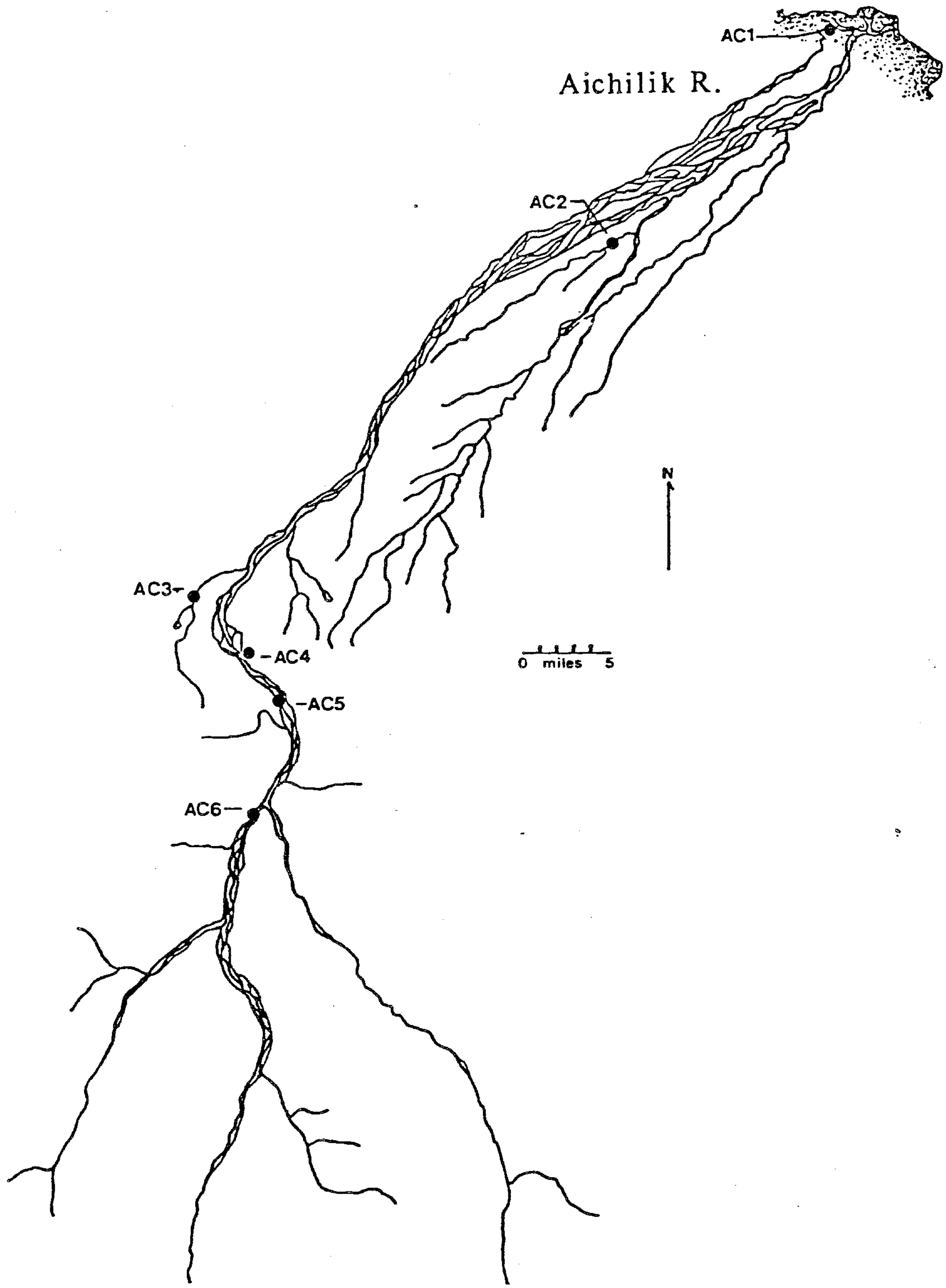


Figure 7. Macroinvertebrate sample locations on the Aichilik River for 1982-1983. (Not all of the drainage is shown)

vegetation is usually sparse. Turbidity and suspended sediments are higher than either spring or tundra stream types. Braided areas may occur in wider valleys, and alluvial fans are sometimes present. Except for deep pools, these streams freeze to the bottom during the winter. The water is essentially poor in minerals and has low conductivity, especially during the spring.

Spring-fed streams within the study area arise near, or within, the streambed of mountain stream channels. Virtually all springs are confined to the foothill or mountain provinces. Some are associated with the Lisbourne limestone group, and others arise from suprapermafrost sources. During the summer, a characteristic feature is the presence of abundant riparian vegetation. Willow (Salix spp.) and alder (Alnus spp.) are the most conspicuous species. The flora is reported to be similar to vegetation found in more temperate climates. Flow and water temperature are more constant than other stream types. Most springs within the study area have a cold water source with temperatures in the vicinity of 5 degrees centigrade at the spring orifice. Thermal springs are also present, and a temperature of 13 degrees centigrade was recorded at Sadlerochit Spring (Kalff and Hobbie 1973). The streambed of springs is almost always covered by a dense mat of moss or algae. Some spring-fed streams maintain open water channels during the winter. As a result, large ice fields (aufeis) form below the spring source. These sheets may attain thicknesses of 4.6 to 6.0 m and some persist through the summer.

Glacier-fed streams comprise a smaller portion of the rivers within the study area, because comparatively few glaciers are present. Where present these streams are immediately noticeable because other portions of a river drainage are affected by them. These types are characterized by low temperatures and low nutrients. Suspended sediment load is highest when the effects of the long photoperiod ablate glaciers the most. A distinct fluctuation in daily flow is observed in these streams with maximum flow in the evening and lowest during the early morning hours. Braided stream channels are a distinctive feature of most of these streams. Craig and McCart (1974) included this category under the mountain stream type. For the purpose of this report, this category will also be included as a mountain stream.

Tundra or lowland streams are characteristic of the coastal or foothill provinces. Flow is restricted to the summer months. Suspended solids concentrations, carried during the spring thaw, tends to be intermediate between spring and mountain streams. The primary source of water is from surface runoff. Because of the water-impermeable permafrost layer, run-off is rapid. Low stream order and low gradient are highly characteristic of these streams. Braided channels may occur in more extensive drainages. Riparian vegetation is primarily comprised of grasses and sedges. The water is generally low to moderate in calcium, nutrients, pH, and conductivity. The water color is often stained yellow or brown. Thaw or beaded streams are sometimes present. These are formed by successional freezing and thawning of the underlying permafrost. These streams tend to be deeper than other types, with slower flow and higher summer temperatures. Substrates range from cobbles to sand and silt.

RESULTS

Chemical Characteristics

Water chemistry for all sites sampled is shown in the Appendix (Table 8). A summary of chemical characteristics by stream type (ie. tundra, mountain, spring) for each major drainage in the study area is presented in Table 1.

Mean total alkalinity values for tundra streams ranged from 51 mg/l in the Angun River Drainage to 146 mg/l in the Sadlerochit Drainage. The mean total alkalinity value for 37 tundra stream sites sampled, was 89 mg/l. Mean alkalinity for mountain streams exhibited similar values, with eleven sites sampled showing a mean of 83 mg/l. Mean alkalinity was highest for the spring stream type (134 mg/l).

Total hardness values showed a similar pattern, with springs having the highest mean concentration (199 mg/l) and tundra and mountain stream types exhibiting lower concentrations (123 mg/l and 129 mg/l, respectively). Marsh creek, a tundra stream had the highest total hardness (281 mg/l). The lowest total hardness concentrations were found at the Niguanak and Angun River sites (51 mg/l and 68 mg/l, respectively).

Conductivity values were very high at spring stream sites, with a mean of 357 umhos/cm. Tundra and mountain streams exhibited moderately high mean values of 176 umhos/cm and 164 umhos/cm, respectively. The lowest conductivity values were found at mountain and tundra stream sites on the Okpilak, Niguanak, and Angun Rivers (less than 100 umhos/cm).

Mean pH values at all locations ranged from 7.1 to 8.0. There was very little difference between the mean pH values of the three stream types.

Physical Characteristics

Physical characteristics for each stream site sampled are found in the Appendix, Table 9. Mean values for physical parameters, by stream order, are presented in Table 2.

Percent gradient ranged from 0.53 to 1.48. First, second, and third order streams exhibited the highest gradients and fourth and fifth order streams exhibited the lowest gradients. Mean values for wetted perimeter increased with stream order and ranged from 2.0 meters, for first order streams, to 34.6 meters, for fifth order streams. Average depth, discharge and average water velocity also increased with stream order. Average depth ranged from 0.24 meters to 0.63 meters. Summer discharge values ranged from 0.08 cms, at first order streams, to 7.23 cms for fifth order streams. Average water velocities ranged from 0.24 m/sec to 0.63 m/sec. Shallow water habitat (less than 0.3 m deep) was predominant at most stream sites and varied little with stream order.

Aquatic Macroinvertebrates

A list of taxa collected, from the 46 locations sampled, is shown in Table 3. A total of 29 taxa were identified, of which, the largest number of taxa were found in the Diptera group.

Table 1. Chemical parameters, for tundra, mountain and spring stream types, from major drainages in the 1002c Study Area, ANWR, Summers of 1982 and 1983.

	No. of sites	Total Alkalinity (mg/l)		Total Hardness (mg/l)		Conductivity (umhos/cm)		pH	
		x̄	range	x̄	range	x̄	range	x̄	range
CANNING R.									
Tundra	3	103	(103)	103	(103)	171	(138-200)	7.8	(7.5-8.0)
Spring	1	137	-	170	-	-	-	8.0	-
TAMAYARIAK R.									
Tundra	4	125	(120-137)	171	(154-205)	243	(225-260)	8.0	(7.7-8.3)
KATAKTURUK R.									
Tundra	2	116	(111-120)	193	(188-198)	275	(270-280)	7.8	(7.8)
Spring	1	116	-	198	-	300	-	7.8	-
CARTER CK.									
Tundra	2	86	(68-103)	77	(68-85)	148	(125-170)	7.8	(7.5-8.0)
MARSH CK.									
Tundra	2	120	(120)	281	(273-289)	370	340-400)	8.5	(8.5)
SADLEROCHIT R.									
Mountain	1	85	-	137	-	240	-	7.8	-
Tundra	4	146	(120-171)	180	(138-221)	303	(250-395)	7.9	(7.8-8.0)
HULAHULA R.									
Mountain	5	92	(68-120)	140	(68-154)	211	(140-340)	7.8	(7.5-8.0)
Tundra	1	86	-	103	-	180	-	7.5	-
OKPILAK R.									
Mountain	3	74	(68-87)	114	(68-154)	68	(30-94)	7.4	(7.3-7.5)
Tundra	4	60	(35-87)	90	(51-137)	97	(44-120)	7.1	(6.8-7.5)
JAGO R.									
Spring	1	137	-	205	-	380	-	8.0	-
Tundra	10	54	(17-107)	86	(34-222)	100	(37-280)	7.1	(6.5-7.7)
NIGUANAK R.									
Tundra	1	68	-	51	-	95	-	8.0	-
ANGUN R.									
Tundra	1	51	-	68	-	74	-	8.0	-
AICHILIK R.									
Mountain	2	73	(60-86)	120	(103-137)	150	(100-200)	7.8	(7.5-8.0)
Tundra	3	91	(34-120)	91	(34-120)	163	(50-230)	7.8	(7.0-8.5)
Spring	1	145	-	222	-	390	-	7.5	-
COMBINED									
Tundra	37	89	(17-171)	123	(34-289)	176	(37-400)	7.6	(6.5-8.5)
Spring	4	134	(116-145)	199	(170-222)	357	(300-390)	7.8	(7.5-8.0)
Mountain	11	83	(60-120)	129	(68-274)	164	(30-340)	7.7	(7.3-8.0)

Table 2. Mean values for physical characteristics of streams sampled in the vicinity of the 1002c Study Area, ANWR, summers of 1982 and 1983.

	STREAM ORDER				
	1	2	3	4	5
Gradient (%)					
$\bar{x}$	0.93	1.48	1.01	0.52	0.54
S.D.	0.85	2.50	1.11	0.19	0.32
N	8	13	14	9	7
Wetted Perimeter (m)					
$\bar{x}$	2.0	5.7	8.6	13.2	34.6
S.D.	2.0	4.7	5.3	8.3	35.2
N	4	11	10	7	3
Average Depth (m)					
$\bar{x}$	0.20	0.22	0.28	0.36	0.32
S.D.	0.06	0.13	0.14	0.11	0.10
N	8	12	12	7	3
Discharge (cms)					
$\bar{x}$	0.08	0.22	0.94	2.80	7.23
S.D.	0.14	0.25	1.13	2.69	5.55
N	5	10	10	7	3
Average Velocity (m/sec)					
$\bar{x}$	0.24	0.25	0.31	0.49	0.63
S.D.	0.25	0.12	0.22	0.35	0.28
N	7	11	12	7	3
% Shallow (< 0.3m)					
$\bar{x}$	90.0	80.0	72.0	63.0	73.0
S.D.	7.1	14.0	24.2	23.8	3.5
N	4	2	8	5	2
Predominant Substrate	Large gravel to small gravel	Large gravel to small gravel	Large gravel	Large gravel	Large gravel to small rubble

Table 3. Aquatic macroinvertebrate taxa collected at forty-six stream locations in the vicinity of the 1002c Study Area, ANWR, Summers of 1982 and 1983.

Platyhelminthes
- Turbellaria
  - Tricladia
    - Planariidae
      - *Dugesia* sp.

Nematomorpha

Annelida
- Oligochaeta

Arthropoda
- Crustacea
  - Amphipoda
    - Gammaridae
      - *Synurella* sp.
- Arachinoidea
- Hydracarina
- Insecta
  - Ephemeroptera
    - Baetidae
      - *Baetis* sp.
    - Heptageniidae
      - *Cinygmula* sp.
    - Metretopodidae
      - *Metretopus* sp.
  - Plecoptera
    - Nemouridae
      - *Nemoura* sp.
      - *Zapada* sp.
    - Chloroperlidae
      - *Alloperla* sp.
      - *Utaperla* sp.
    - Perlodidae
      - *Isoperla* sp.
    - Capniidae
    - Leuctridae
  - Trichoptera
    - Limnephilidae
      - *Dicosomoecus* sp.
      - *Ecclisomyia* sp.
  - Coleoptera
    - Dytiscidae
      - *Agabus* sp.
  - Diptera
    - Empididae
    - Psychodidae
      - *Pericoma* sp.
    - Rhagionidae
      - *Atherix* sp.
    - Tipulidae
      - *Pedicia* sp.
      - *Tipula* sp.
    - Simuliidae
      - *Prosimulium* sp.
    - Chirnomidae
      - Chironominae
      - Diamesinae
      - Orthocladiinae
      - Tanypodinae

Mollusca
- Gastropoda
  - Physidae
    - Physa

Distribution

A list of taxa and their relative abundance, by sampling location, is presented in the Appendix, Table 10. Frequency of occurrence of taxonomic groups by stream type is shown in Table 4. A total of 10 taxa were collected in mountain streams and 22 taxa were collected in tundra and in spring streams (Table 4). Oligochaetes, <u>Baetis</u> sp., <u>Cinygmula</u> sp., <u>Nemoura</u> sp., Capniidae, <u>Prosimulium</u> sp., Diamesinae and Orthocladiinae were found in all stream types. Mountain streams had few taxa, with those taxa being represented by low to moderate frequency among the sampling sites. Tundra sites had a large number of taxa, however, many of the taxa exhibited a low frequency of occurence. Spring stream sites also had a high number of taxa, but with most of the taxa occuring in greater frequency than that found for tundra streams. More taxa of Plecoptera and Diptera were represented at spring stream sites than at tundra and mountain stream types.

Species Composition

Percent composition of major taxanomic groups of aquatic macroinvertebrates collected in the study area is shown in Table 5 and Figure 8.

Mountain and tundra streams exhibited similar species compositions. Orthocladiinae, Simuliidae, and Ephemeroptera were the predominant taxa collected at these sites, with these taxa representing 84 percent of the composition in both tundra and mountain stream types. Tundra streams were represented by many more taxa than found in mountain streams, however they only accounted for a small part of the population.

Orthocladiinae was the predominant taxa found in spring streams, which accounted for 76 percent of the species composition. Spring streams were similar to tundra streams in numbers of taxa, only. Percent composition of Diamesinae was similar in both mountain and spring streams. Composition of Oligochaetes was greater in spring streams than in mountain and tundra streams.

Macroinvertebrate Abundance and Diversity

Statistical analysis of data and mean values for density, biomass, diversity and evenness are shown in Tables 11 - 13, in the appendix. Mean values for density, biomass, diversity, evenness, and number of taxa are shown in Table 6 and in Figures 9 - 11.

Density of organisms was greatest in spring stream samples (13,263 organisms/m^2. Mean density of organisms in tundra streams (1068 organisms/m^2 was nearly an order of magnitude greater than in mountain streams (208 organisms/m^2). Biomass of organisms showed a similar trend, with much less variation between mean values for the three stream types.

Mean diversity (H') and evenness (J') was much greater for the tundra stream type (H' = 1.689, J' = 0.670). Diversity was lowest in mountain stream samples (0.676) and can be attributed primarily to the low number of taxa found at these sites ($\overline{x}$ = 3.5 taxa/site). Spring streams exhibited the highest mean number of taxa (9.25 taxa/site), however, the extreme redundancy of, primarily, chironomid larvae, contributed to the low evenness value (0.284) and consequently, the low diversity value (0.855).

Table 4. Frequency of occurrence of aquatic macroinvertebrate taxa collected in the vicinity of the 1002c Study Area, ANWR, Summers of 1982 and 1983.

	STREAM TYPE		
	Tundra	Mountain	Spring
No. of Sites	(32)	(10)	(4)
Platyhelminthes			
Turbellaria			
Tricladia			
Planariidae			
Dugesia sp.	9.4	0.0	50.0
Nematomorpha	3.1	0.0	0.0
Annelida			
Oligochaeta	87.5	20.0	75.0
Arthropoda			
Crustacea			
Amphipoda			
Gammaridae			
Synurella sp.	9.4	0.0	25.0
Arachnoidea			
Hydracarina	53.1	0.0	25.0
Insecta			
Ephemeroptera			
Baetidae			
Baetis sp.	78.1	40.0	50.0
Heptageniidae			
Cinygmula sp.	65.5	20.0	50.0
Metretopodidae			
Metretopus sp.	6.3	0.0	0.0
Plecoptera			
Nemouridae			
Nemoura sp.	93.7	40.0	50.0
Zapada sp.	0.0	0.0	25.0
Chloroperlidae			
Alloperla sp.	0.0	0.0	25.0
Utaperla sp.	0.0	0.0	25.0
Perlodidae			
Isoperla sp.	0.0	10.0	25.0
Capniidae	46.9	30.0	50.0
Leuctridae	9.4	0.0	0.0
Trichoptera			
Limnephilidae			
Dicosomoecus sp.	6.3	0.0	0.0
Ecclisomyia sp.	6.3	0.0	25.0
Coleoptera			
Dytiscidae			
Agabus sp.	6.3	0.0	0.0
Diptera			
Empididae	0.0	0.0	25.0
Psychodidae			
Pericoma sp.	0.0	0.0	25.0
Rhagionidae			
Atherix sp.	0.0	0.0	50.0
Tipulidae			
Pedicia sp.	9.4	0.0	50.0
Tipula sp.	53.1	0.0	25.0
Simuliidae			
Prosimulium sp.	87.5	30.0	75.0
Chirnomidae			
Chironominae	40.6	0.0	25.0
Diamesinae	34.4	50.0	75.0
Orthocladiinae	100.0	100.0	100.0
Tanypodinae	21.9	10.0	0.0
Mollusca			
Gastropoda			
Physidae			
Physa sp.	9.4	0.0	0.0
No. of taxa	22	10	22

Table 5. Percent composition for major taxonomic groups of aquatic macroinvertebrates, 1002c, Study Area, ANWR.

Taxa		Stream Type		
		Tundra	Mountain	Spring
Platyhelminthes				
	Planariidae	0.02	-	0.64
Nematomorpha		0.01	-	-
Annelida				
	Oligochaeta	3.02	1.30	8.60
Arthropoda				
	Gammaridae	0.30	-	0.11
Arachnoidea				
	Hydracarina	1.80	-	0.03
Insecta				
	Ephemeroptera	(23.46)	(22.03)	(0.38)
	Baetidae	13.98	13.61	0.27
	Heptageniidae	9.43	8.42	0.11
	Metretopodiae	0.05	-	-
	Plecoptera	(7.4)	(5.4	(1.24)
	Nemouridae	6.15	3.24	0.42
	Chloroperlidae	-	-	0.79
	Perlodidae	-	0.22	0.01
	Capniidae	1.17	1.94	0.02
	Leuctridae	0.08	-	-
	Trichoptera	(0.07)	-	(1.56)
	Limnephilidae	0.07	-	-
	Coleoptera	(0.04)	-	-
	Dytiscidae	0.04	-	-
	Diptera	(63.84)	(71.27)	(87.42)
	Empididae	-	-	0.11
	Psychodidae	-	-	0.24
	Rhagionidae	-	-	0.70
	Tipulidae	0.51	-	0.11
	Simuliidae	35.81	46.00	0.86
	Chironomidae	(27.52)	(25.27)	(85.40)
	Chironominae	1.18	-	0.01
	Diamesinae	0.96	8.64	9.32
	Orthocladiinae	25.10	16.41	76.07
	Tanypodinae	0.28	0.22	-
Mollusca				
	Physidae	0.04	-	-

Percent composition represents combined samples for all stations under each stream type.

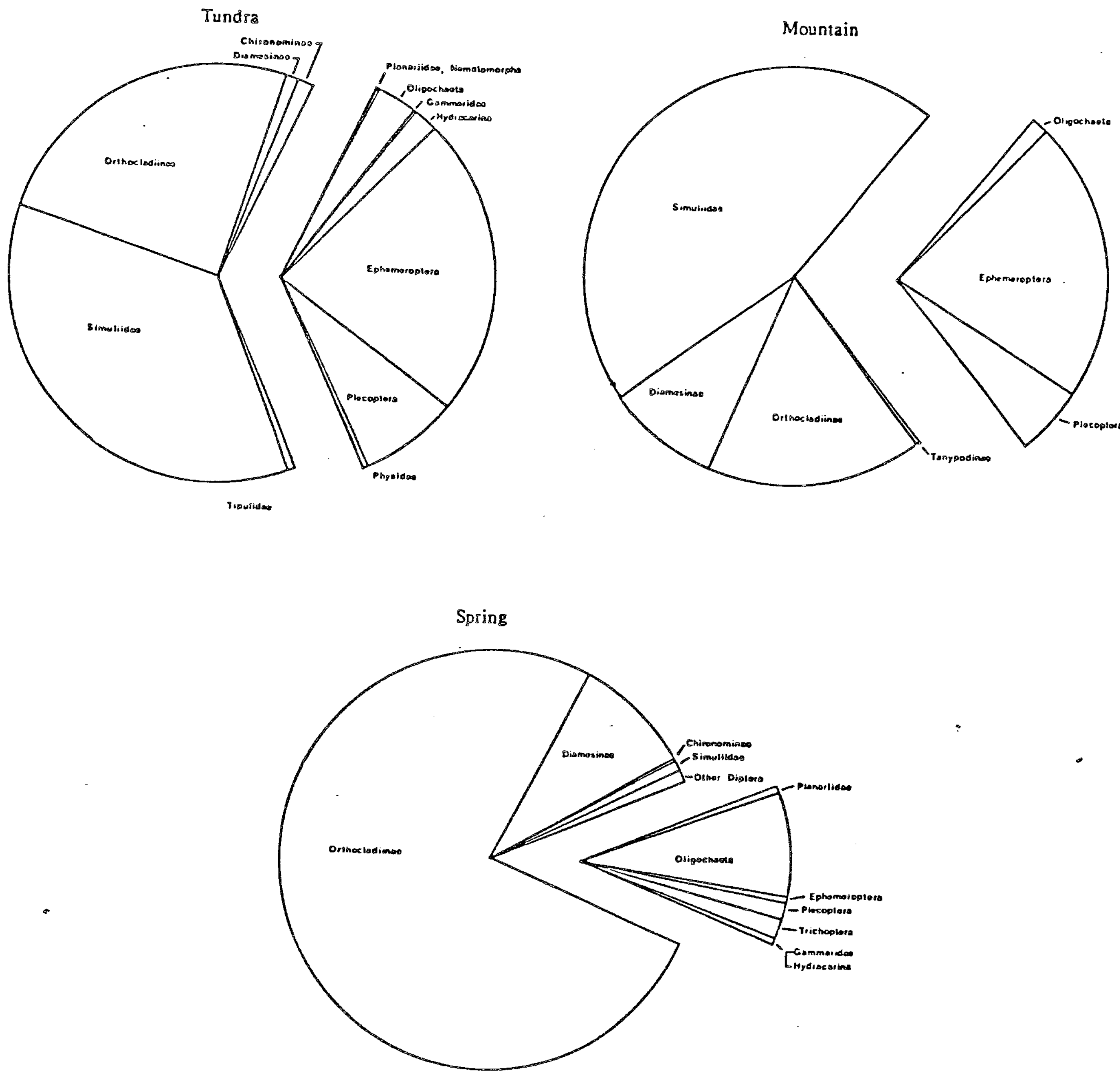
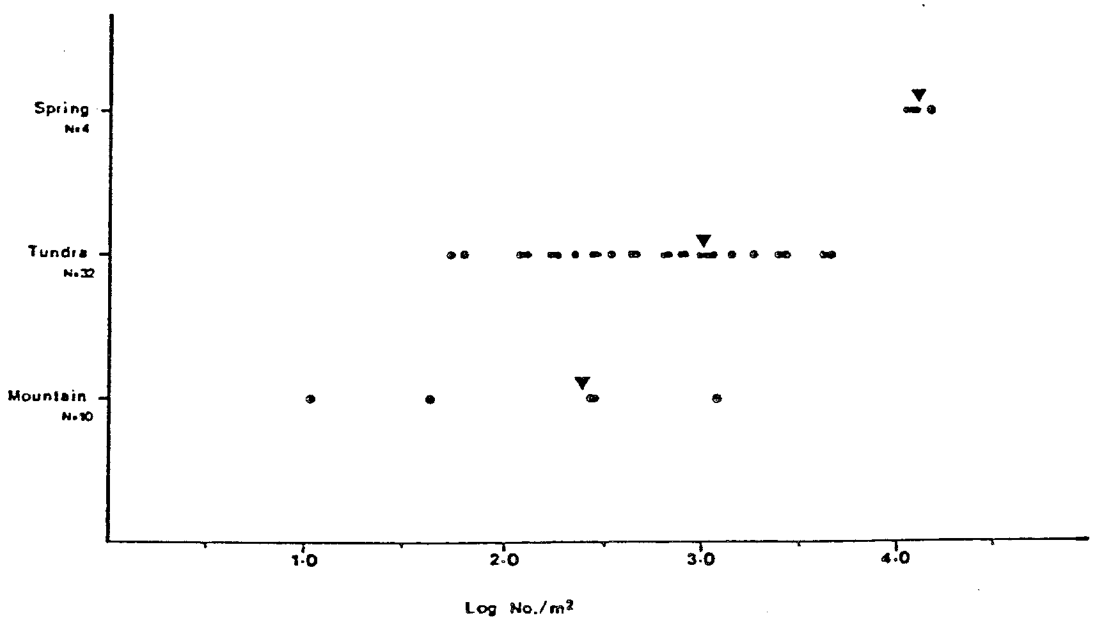


Figure 8. Percent composition for major taxonomic groups of aquatic macroinvertebrates, 1002c Study Area, ANWR.



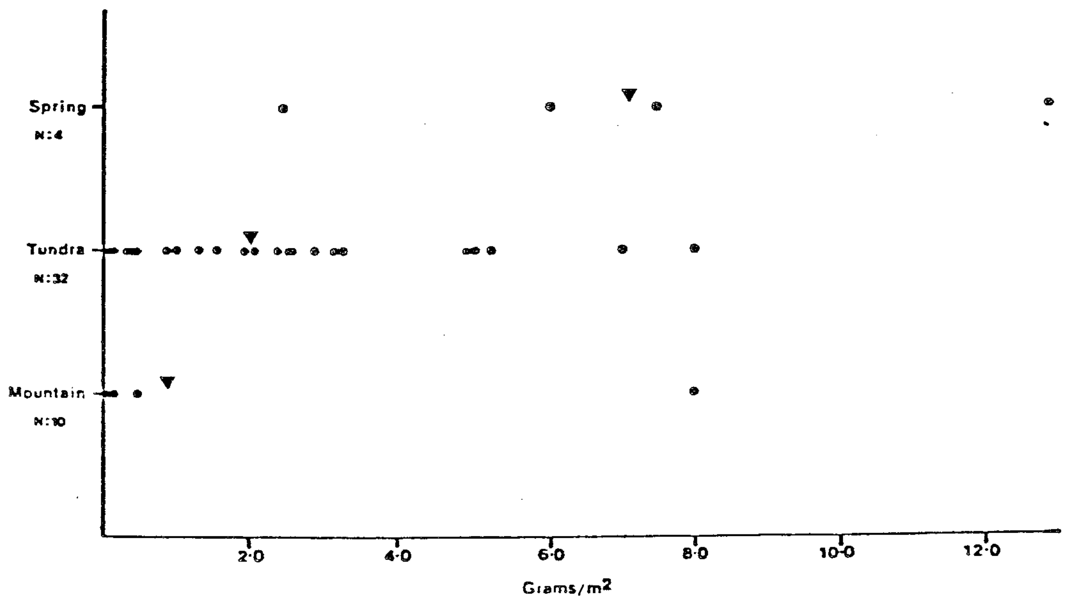


Figure 9. Log number/m^2 and grams/m^2 ($\overline{x}$ = ▼) for aquatic macroinvertebrates collected in the vicinity of the 1002c Study Area, ANWR.

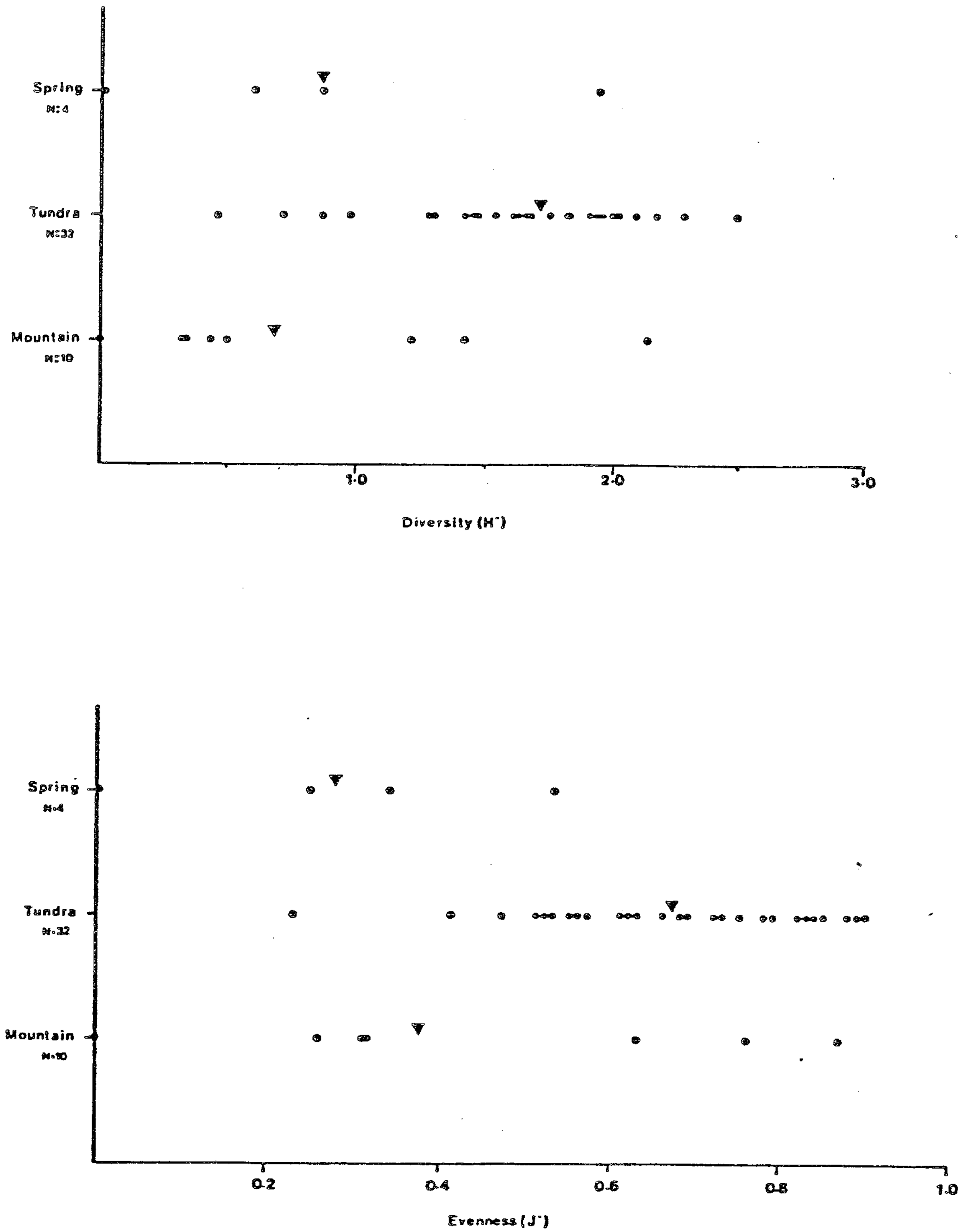


Figure 10. Diversity (H') and Evenness (J') for aquatic macroinvertebrates ($\bar{x}$ = ▼) collected in the vicinity of the 1002c Study Area, ANWR.

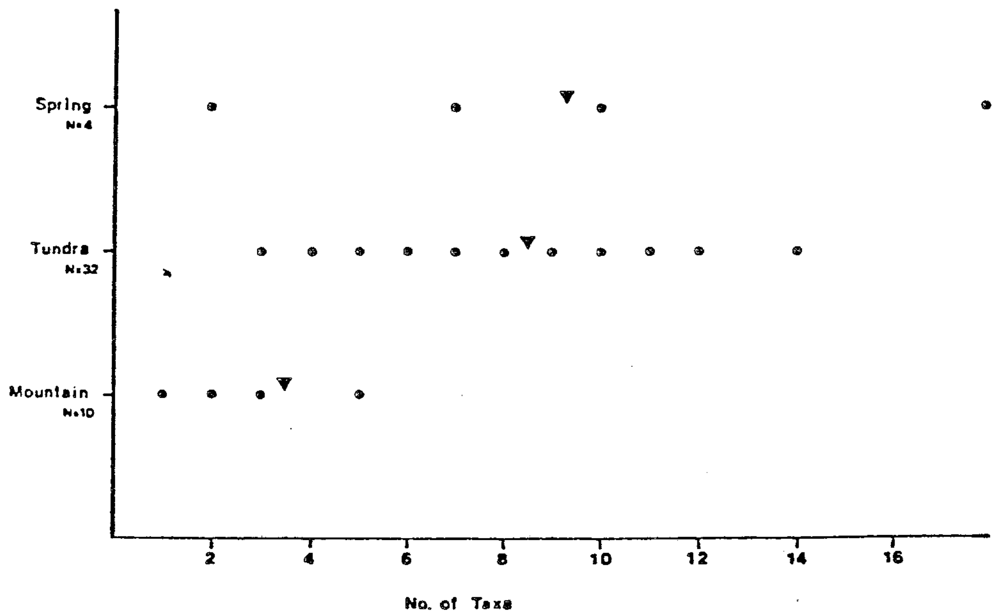


Figure 11. Number of taxa ($\overline{x}$ = ▼) for aquatic macroinvertebrate samples collected in the vicinity of the 1002c Study Area, ANWR.

Table 6. Mean density (no./m^2), biomass (gms/m^2), diversity (H'), evenness (J'), and number of taxa ($\pm$ standard error), by stream type, 1002c Study Area, ANWR.

	Stream Type		
	Tundra	Mountain	Spring
No. of Samples	32	10	4
Density			
no./m^2	1068.0 $\pm$ 207.7	207.8 $\pm$ 118.4	13,263.0 $\pm$ 816
Biomass			
gms/m^2	2.023 $\pm$ 0.359	0.897 $\pm$ 0.796	7.152 $\pm$ 2.179
Diversity			
H'	1.689 $\pm$ 0.084	0.676 $\pm$ 0.216	0.855 $\pm$ 0.402
Evenness			
J'	0.670 $\pm$ 0.027	0.377 $\pm$ 0.092	0.284 $\pm$ 0.106
No. of Taxa			
No.	8.46 $\pm$ 0.45	3.50 $\pm$ 0.60	9.25 $\pm$ 3.35

Regression analysis of selected physical parameters with macroinvertebrate density, biomass, diversity, and eveness values are shown in Table 7. Scatterplots, of the significant regressions ($P < 0.05$, $r \neq 0$), are shown in Figures 12 - 14, in the appendix.

There were no significant correlations with discharge. There was a significant positive correlation ($P = 0.05$) between biomass and average velocity. Diversity and evenness values did not show any significant correlations with any of the physical parameters. Strong positive correlations ($P < 0.01$) were found between density and biomass of macroinvertebrates with both conductivity and alkalinity values. The highest correlation ($r = +0.541$, $P = 0.001$) was between density of invertebrates and water conductivity.

Table 7. Regression analysis of physical parameters with density, biomass, diversity and evenness of aquatic macroinvertebrates from the 1002c, Study Area, ANWR.

INDEPENDENT VARIABLES	DEPENDENT VARIABLES Density(log_{10})	Biomass	Diversity	Evenness
Discharge				
n	40	40	40	40
r	-0.106	+0.202	-0.157	-0.92
Significance Level	N.S.	N.S.	N.S.	N.S.
Average Velocity				
n	37	37	37	37
r	+0.063	+0.338	-0.073	-0.167
Significance Level	N.S.	0.05	N.S.	N.S.
Conductivity				
n	45	45	45	45
r	+0.541	+0.464	+0.042	-0.074
Significance Level	0.001	0.005	N.S.	N.S.
Alkalinity				
n	46	46	46	46
r	+0.462	+0.398	+0.109	+0.027
Significance Level	0.005	0.01	N.S.	N.S.

n = Sample Size
r = Correlation Coefficient
Significance Level = P(r = 0)

DISCUSSION

Invertebrate densities for this study ranged from 11 organisms/m^2 to 15,555 organisms/m^2. These values may be close to seasonal minimum densities due to the midsummer sampling scheme. Cowan and Oswood (unpublished) and Hynes (1970) stated that benthic invertebrate populations generally exhibited lowest densities during midsummer. Craig and McCart (1974) reported a range in densities from 22 organisms/m^2 to 84,000 organisms/m^2, for samples collected in the general vicinity of the study area. They concluded that tundra and spring streams had densities much the same as southern latitude streams, however, mountain streams exhibited much lower densities. Platts et.al. (1983) reported that densities of benthic invertebrates, in Rocky Mountain streams in Utah, Idaho, Colorado and Wyoming, ranged from 1000 organisms/m^2 to 10,000 organisms/m^2.

This study supports the stream classification system developed by Craig and McCart (1974). Invertebrate density and biomass values were very similar to their findings. Macroinvertebrate density was generally an order of magnitude greater from mountain to tundra streams and from tundra to spring streams. The classification scheme generally reflects the stream stability. Mountain streams, exhibiting the lowest densities, have greater fluctuations in discharge, turbidity (particularly those with glacial water sources) and greater instability of substrate. Tundra streams exhibit intermediate stability while spring streams are very stable.

The amount and type of organic matter in the streams may greatly influence the density biomass and distribution of stream invertebrates (Anderson and Sedell, 1975; Egglishaw, 1964; and, Cowan and Oswood, unpublished). From observations of riparian vegetation it appears that allochthonous organic input decreases from spring streams to tundra streams and from tundra to mountain streams. The autochthonous organic components of these stream types appear to follow the same pattern. Dense growths of algae have been observed at all of the spring stream sites. Increased turbidity at many of the mountain stream sites may severely limit autotrophic production. Using conductivity and alkalinity as an index of production, results indicated very little difference between mountain and tundra streams. Spring streams had much higher values for conductivity and alkalinity. Density and biomass of aquatic invertebrates showed strong correlation with alkalinity and conductivity values.

Merrit and Cummins (1978) classified aquatic invertebrate taxa by functional group (i.e. collector - gatherer, scrapers, shredder etc). Species composition of all three stream types was dominated by the collector - gatherer and scraper functional groups (ie. Simuliidae, Orthocladinae, Diamesinae, Baetidae, and Oligochaeta), which generally feed on fine particulate organic matter. Shredder species, which primarilly feed on leaf litter, exhibited very low densities. The scarcity of allochthonous organic matter is reflected by the sparse distribution of species in the shredder functional group. At higher altitudes and latitudes, riparian vegetation is restricted and streams are primarily autotrophic with the collector functional group dominating the macroinvertebrate community (Vannote et. al., 1980). The low diversity of functional groups is reflected in the low values found for species diversity (H'), throughout the study area. Diversity values ranged from 0.001 to 2.479, with the majority being less than 1.5. Brunskill et. al. (1973) noted a decline in diversity of benthic invertebrates with increasing latitude.

Mean diversity (H') and evenness (J') values for mountain and spring streams were very low. low values for mountain streams reflect the instability of these waters. Spring streams exhibit highly stable conditions. Low diversity values in these waters results from the uneven distribution of taxa within the benthic community structure. At these sites, chironomids accounted for 85% of the species composition. Vannote et. al. (1980) stated that systems with highly stable physical structure may have low biotic diversity yet maintain ecosystem stability. Tundra streams exhibited the highest diversity and evenness values. This may be partially explained by the wide range of temperatures found in these waters. Under these conditions, optimum temperatures will occur for a larger number of species than if the thermal regime displayed minimum variance (Vannote et. al., 1980).

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APPENDIX

Table 8. Chemical characteristics for all stream locations sampled in the vicinity of 1002c Study Area, ANWR, Summers of 1982 and 1983.

Location	Dissolved Oxygen (mg/1)	Total Alkalinity (mg/1)	Total Hardness (mg/1)	Conductivity umhos/cm	pH
CANNING R.					
CN-1	10	103	103	200	8.0
CN-2	10	103	103	175	7.9
CN-3	10	103	103	138	8.0
CN-4 Spring	10	137	170	-	8.0
TAMAYARIAK R.					
TM-1	10	124	205	260	7.7
TM-2	10	120	154	225	8.3
TM-3	10	137		260	7.8
TM-4	11	120	154	225	8.3
KATAKTURUK R.					
KT-1	8	120	188	270	7.8
KT-2	11	111	198	280	7.8
KT-3 Spring	7	116	198	300	7.8
CARTER CK.					
CA-1		103	85	170	7.5
CA-2	10	68	68	125	8.0
MARSH CK.					
MA-1		120	273	340	8.5
MA-2		120	289	400	8.5
SADLEROCHIT R.					
SA-1	7	85	137	240	7.8
SA-2	10	154	154	255	8.0
SA-3	8	171	221	310	8.0
SAI-1	7	120	205	395	7.8
SAI-2	10	137	138	250	7.8
HULAHULA R.					
HH-1		120	154	270	8.0
HH-2		86	103	180	7.5
HH-3		103	120	155	8.0
HH-4		68	86	140	7.5
HH-5		68	68	150	7.5
HH-6		103	274	340	8.0

Table 8. Continued.

Location	Dissolved Oxygen (mg/l)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Conductivity umhos/cm	pH
OKPILAK R.					
OK-1		68	120	80	7.5
OK-2		87	103	44	7.0
OK-3		86	154	30	7.5
OK-4		68	137	120	7.5
OK-5	9	51	51	110	7.0
OK-6		35	70	115	6.8
OK-7		68	68	94	7.3
JAGO R.					
JA-1	10	43	103	72	6.9
JA-2	9	43	120	92	6.9
JA-3		51	51	68	6.8
JA-4	7	67	51	88	6.9
JA-5	9	47	86	80	6.7
JOK-1	9	107	222	280	7.7
JOK-2 Spring		137	205	380	8.0
JI-1	9	56	51	72	7.5
JOP-1	10	43	68	80	7.2
JOP-2		17	34	37	6.5
JOP-3		70	70	130	7.5
NIGUANAK R.					
NI-1		68	51	95	8.0
ANGUN R.					
AN-1		51	68	74	8.0
AICHILIK R.					
AC-1	10	120	120	230	8.0
AC-2		34	34	50	7.0
AC-3		120	120	210	8.5
AC-4 Spring	13	145	222	390	7.5
AC-5	11	86	137	200	8.0
AC-6	9	60	103	100	7.5

Table 9. Physical characteristics for all stream locations sampled, 1002c Study Area, Summer of 1982 and 1983.

Location	Stream Type	Stream Order	Gradient %	Channel Type	Wetted Perimeter (m)	Ave. Depth (m)	Discharge (cms)	Ave. Velocity (m/sec)	% Pool (> 0.3m)	% Shallow (< 0.3m)	Predominant Substrate
CANNING											
CN-1	Tundra	4	0.45	Irregular	4.0	0.20	0.20	0.52	40	60	Large and small gravel
CN-2	Tundra	2	0.65	Straight	1.2	0.15	0.06		30	70	Large and small gravel
CN-3	Tundra	1	0.60	Straight	1.0	0.30	0.03		10	95	Cobble and large gravel
CN-4	Spring	1	3.00	Straight	1.2	0.20	0.57	0.77	10	90	Rubble-cobble
TAMAYARIAK											
TM-1	Tundra	5	0.28	Irregular	10.0	0.30	2.65	0.34	25	75	Large and small gravel
TM-2	Tundra	4	0.90	Irregular	4.0	0.50	0.79	0.12	60	40	Large and small gravel
TM-3	Tundra	4	0.79	Irregular	6.5	0.30	4.26	0.62	15	85	Rubble-cobble
TM-4	Tundra	3	0.75	Irregular	7.0	0.40	3.20	0.62	10	90	Rubble-cobble
KATAKTURUK											
KT-1	Tundra	5	0.30	Braided	18.8	0.43	5.64	0.89			
KT-2	Tundra	3	1.40	Straight							
KT-3	Spring	1	0.85	Braided	3.5	0.15	0.08	0.15			
CARTER CK.											
CA-1	Tundra	3	0.38	Irregular	4.3	0.12	0.10	0.21			
CA-2	Tundra	3	0.75	Straight	2.5	0.20	0.20	0.22	30	70	Large and small gravel
MARSH CK.											
MA-1	Tundra	3	0.21	Irregular	7.0	0.21	0.68	0.15	20	80	Large and small gravel
MA-2	Tundra	3	0.63	Irregular	5.0	0.18	0.46	0.24	10	90	Large and small gravel
SADELROCHIT R.											
SA-1	Mountain	5	0.30	Braided	75.0	0.23	13.40	0.68	30	70	Rubble-cobble
SA-2	Tundra	1	0.50	Meandering	1.0	0.18	0.01	0.09	20	80	Small gravel - silt
SA-3	Tundra	1	0.70	Meandering	5.0	0.28	0.01	0.02	5	95	Small gravel - silt
ITKILYARIAK											
SAI-1	Tundra	4	0.40	Irregular	20.0	0.30	1.85	0.40	10	90	Rubble - large gravel
SAI-2	Tundra	4	0.40	Irregular							
HULAHULA R.											
HH-1	Glacial Mount.	5	0.30	Braided							
HH-2	Tundra	2	0.38	Irregular	2.7	0.21	0.01	0.06			
Old Man Ck.											
HH-3	Mountain	2	2.84	Straight	10.2	0.27	0.78	0.30			
Katak Ck.											
HH-4	Mountain	3	3.25	Straight	16.5	0.18	1.47	0.52			
W. Patuk											
HH-5	Mountain	2	9.50	Straight	14.6	0.15	1.02	0.49	10	90	Small and large gravel
E. Patuk											
HH-6	Mountain	3	3.80	Straight	13.4	0.34	3.40	0.79	5	95	Small and large gravel

Table 9. Continued.

Location	Stream Type	Stream Order	Gradient %	Channel Type	Wetted Perimeter (m)	Ave. Depth (m)	Discharge (cms)	Ave. Velocity (m/sec)	% Pool (>0.3m)	% Shallow (<0.3m)	Predominant Substrate
OKPILAK R.											
OK-1	Glacial Mount.	5	0.95	Braided							
OK-2	Tundra	3	0.69	Irregular	7.3	0.26	0.16	0.09	80	20	Large and small gravel
OK-3	Glacial Mount.	5									
OK-4	Tundra	4	0.61	Irregular	15.4	0.52	0.23	0.03	60	40	Large and small gravel
OK-5	Tundra,	3	0.66	Irregular	7.7	0.30	0.40	0.19	30	70	Large and small gravel
OK-6	Tundra	3	0.64	Irregular	9.4	0.26	0.28	0.12	40	60	Boulder-rubble
OK-7	Glacial Mount.	4	0.36	Braided							
JAGO R.											
JA-1	Tundra	2	0.28	Straight	6.0	0.35	0.39	0.20			
JA-2	Tundra	1	0.70	Irregular	4.6	0.23	0.34	0.35			
JA-3	Tundra	2	0.56	Irregular	1.5	0.55	0.14	0.18			
JA-4	Tundra	1	0.75	Irregular	0.8	0.17	0.02	0.16			
JA-5	Tundra	2	0.45	Irregular	2.2	0.27	0.11	0.19			
OKEROKOVIK											
JOK-1	Tundra	4	0.35	Braided	23.7	0.32	6.64	0.95			
JOK-2	Spring	1	0.30	Straight	3.0	0.12	0.14	0.12			
IGILATAVIK											
JI-1	Tundra	4	0.45	Irregular	19.1	0.38	5.66	0.85			
OKPIROURAK											
JOP-1	Tundra	3	0.28	Meandering	19.1	0.65	2.81	0.25			
JOP-2	Tundra	3	0.47	Straight			0.03				
JOP-3	Tundra	3	0.23	Irregular	16.8	0.21	1.14	0.34			
NIGUANAK R.											
NI-1	Tundra	2	0.25	Irregular	14.0	0.18	0.89	0.37			
ANGUN R.											
AN-1	Tundra	2	0.54	Irregular	12.2	0.15	0.21	0.12			
AICHILIK R.											
AC-1	Tundra	2	0.20	Irregular							
AC-2	Tundra	2	0.94	Irregular	3.7	0.12	0.12	0.27			
AC-3	Tundra	2	1.50	Straight	1.8	0.09	0.03	0.21			
AC-4	Spring	2	1.13	Straight	3.0	0.13	0.14	0.33			
AC-5	Glacial Mount.	5	0.95	Braided							
AC-6	Glacial Mount.	5	0.70	Irregular							

Table 10. Relative abundance and distribution of aquatic macroinvertebrates collected in the vicinity of the 1002c Study Area, ANWR, Summers of 1982 and 1983.

TAXA	CANNING R.				TAMAYARIAK R.				KATAKTURUK R.			CARTER CK.		MARSH CK.	
	CN-1	CN-2	CN-3	CN-4**	TM-1	TM-2	TM-3	TM-4	KT-1	KT-2	KT-3	CA-1	CA-2	MA-1	MA-2
Platyhelminthes															
Turbellaria															
Tricladia															
Planariidae															
Dugesia sp.		R		A				R					R		
Nematomorpha															
Annelida															
Oligochaeta	R	R	C	A	R	C	R	R	R		C	R	C	C	C
Arthropoda															
Crustacea															
Amphipoda															
Gammaridae															
Synurella sp.															
Arachinoidea															
Hydracarina		C	C	R			R					A	R	C	R
Insecta															
Ephemeroptera															
Baetidae															
Baetis sp.	C	C	A	C	C	A	C	R	A	C	C	A	C	A	A
Heptageniidae															
Cinygmula sp.	A	C		R	C	A	A	C	C	R	C	C	A	A	C
Metretopodidae															
Metretopus sp.															
Plecoptera															
Nemouridae															
Nemoura sp.	C	A	C		R	C	C	C	A	C	C	A	A	C	C
Zapada sp.				A											
Chloroperlidae															
Alloperla sp.				A											
Utaperla sp.				A											
Perlodidae															
Isoperla sp.				A											
Capniidae	C			R	C	C	C	R	C			C		R	R
Leuctridae															
Trichoptera															
Limnephilidae															
Dicosomoecus sp.															
Ecclisomyia sp.				A								R			
Coleoptera															
Cytiscidae															
Agabus sp.															
Diptera															
Empididae				C											
Psychodidae															
Pericoma sp.				C											
Rhagionidae															
Atherix sp.				A											
Tipulidae															
Pedicia sp.		R		C											
Tipula sp.	R		R			R	R					R		R	R
Simuliidae															
Prosimulium sp.	R		C	R	A	A	A	C	A	C	A	A	R	A	A
Chirnomidae															
Chironominae		A		R								C			R
Diamesinae		R		A							A				
Orthocladiinae	C	A	A	A	R	A	C	R	C	R	A	A	C	A	A
Tanypodinae	R					R	R					C	R		
Mollusca															
Gastropoda															
Physidae															
Physa sp.		R	R												
No. of Taxa	9	11	8	19	7	9	10	7	7	5	7	12	9	9	10

*Relative abundance: R= < 5/ft^2, C= 6-25/ft^2, A= > 25/ft^2.
**Spring Locations.

Table 10. Continued.

TAXA	ANGUN R. AN-1	NIGUANAK R. NI-1	JAGO R. JA-3	JA-4	JA-5	JOP-1	JOP-2	JOP-3	JOK-2**	AICHILIK R. AC-2	AC-3	AC-4**	AC-6
Platyhelminthes													
Turbellaria													
Tricladia													
Planariidae													
Dugesia sp.									R				
Nematomorpha													
Annelida													
Oligochaeta	C		A		R	R	R	C	R	C	R		
Arthropoda													
Crustacea													
Amphipoda													
Gammaridae													
Synurella sp.	C		A		R	R	R	C	R	C	R		
Arachinoidea													
Hydracarina			R				R	R			C		
Insecta													
Ephemeroptera													
Baetidae													
Baetis sp.		R					R	C		C	A		
Heptageniidae													
Cinygmula sp.		R						R		R	R		
Metretopodidae													
Metretopus sp.							R						
Plecoptera													
Nemouridae													
Nemoura sp.	R	R	R		R		C	R	R	C	A		
Zapada sp.													
Chloroperlidae													
Alloperla sp.													
Utaperla sp.													
Perlodidae													
Isoperla sp.												R	
Capniidae		C	R					R			R		R
Leuctridae	R	R											
Trichoptera													
Limnephilidae													
Dicosmoecus sp.				R			R						
Ecclisomyia sp.								R					
Coleoptera													
Cytiscidae													
Agabus sp.				R			R						
Diptera													
Empididae													
Psychodidae													
Pericoma sp.													
Rhagionidae													
Atherix sp.									R				
Tipulidae													
Pedicia sp.								R	R				
Tipula sp.	C		R					R	R		R		
Simuliidae													
Prosimulium sp.	R	C	R	C	R	R	A	A	A	A	A		
Chirnomidae													
Chironominae		R	R				C	R		C	R		
Diamesinae	C	R	R					R	A		C		A
Orthocladiinae	A	A	C	C	R	C	C	A	A	A	A	A	A
Tanypodinae								R					
Mollusca													
Gastropoda													
Physidae													
Physa sp.													
No. of Taxa	8	9	9	4	4	3	10	14	10	8	12	2	3

*Relative abundance: R = < $5/ft^2$, C = $6-25/ft^2$, A = > $25/ft^2$.
**Spring Locations.

Table 10. Continued.

TAXA	SA-1	SA-2	SA-3	SAI-1	SAI-2	HH-1	HH-2	HH-3	HH-4	HH-5	HH-6	OK-1	OK-2	OK-3	OK-4	OK-5	OK-6	OK-7
	SADELROCHIT R.					HULAHULA R.						OKPILAK R.						
Platyhelminthes																		
Turbellaria																		
Tricladia																		
Planariidae																		
Dugesia sp.																		
Nematomorpha																	R	
Annelida																		
Oligochaeta		A	R	R	R		R	R	R				C		C	R	R	
Arthropoda																		
Crustacea																		
Amphipoda																		
Gammaridae																		
Synurella sp.																		
Arachinoidea																		
Hydracarina		A		R	C		R									R	R	
Insecta																		
Ephemeroptera																		
Baetidae																		
Baetis sp.	A	A		A	A	R	A	C		R				R	R	A		
Heptageniidae																		
Cinygmula sp.	A		R	A	R		R	C						R	A			
Metretopodidae																		
Metretopus sp.															R			
Plecoptera																		
Nemouridae																		
Nemoura sp.	R	C	C	C	A	R	C	R			C		C		A	R	R	
Zapada sp.																		
Chloroperlidae																		
Alloperla sp.																		
Utaperla sp.																		
Perlodidae																		
Isoperla sp.						R												
Capniidae				R											R		R	R
Leuctridae													R					
Trichoptera																		
Limnephilidae																		
Dicosomoecus sp.																		
Ecclisomyia sp.																		
Coleoptera																		
Cytiscidae																		
Agabus sp.																		
Diptera																		
Empididae																		
Psychodidae																		
Pericoma sp.																		
Rhagionidae																		
Atherix sp.																		
Tipulidae																		
Pedicia sp.																R		
Tipula sp.				R	R		R						R		C		R	
Simuliidae																		
Prosimulium sp.	A	A		A	A		A	C						R	A		C	
Chironomidae																		
Chironominae			R				C								R		R	
Diamesinae		A		R	C	R		R		R	R		R		R			
Orthocladiinae	C	A	C	R	A	R	A	C	R	R	R	R	C	R	A	C	A	R
Tanypodinae				R						R							R	
Mollusca																		
Gastropoda																		
Physidae																		
Physa sp.							R											
No. of Taxa	5	7	5	11	9	5	10	7	2	5	3	1	6	2	10	8	11	2

*Relative abundance: R= $< 5/ft^2$, C= $6-25/ft^2$, A= $> 25/ft^2$.
**Spring Locations.

Table 11. Statistical analysis of raw and transformed data for number of organisms/sample, from all stations, 1002c Study Area, ANWR.

Station	Sample Size	RAW DATA Mean No.	Standard Deviation	Standard Error	% Precision	TRANSFORMED DATA LOG (x+1) Mean	Derived Mean	Standard Deviation	Standard Error	% Precision
CANNING R.										
CN-1	3	78	13.05	7.53	9.7	1.89	78	0.07	0.04	2.0
CN-2	3	62	12.53	7.23	11.7	1.79	62	0.09	0.05	2.8
CN-3	2	259	7.78	5.50	2.1	2.41	256	0.01	0.01	0.4
*CN-4	3	950	964.12	556.63	58.5	2.83	1102	0.43	0.25	8.7
TAMAYARIAK R.										
TM-1	3	30	11.59	6.69	22.3	1.47	32	0.18	0.10	6.9
TM-2	3	162	99.14	57.23	35.3	2.14	184	0.33	0.19	9.0
TM-3	3	82	100.46	58.00	70.7	1.70	103	0.52	0.30	17.7
TM-4	3	11	4.04	2.33	21.2	1.08	12	0.13	0.08	7.1
KATAKTURUK R.										
KT-1	3	332	337.44	194.82	58.7	2.37	400	0.45	0.26	11.0
KT-2	3	16	4.93	2.84	17.8	1.23	17	0.12	0.07	5.5
*KT-3	3	920	613.83	354.39	38.5	2.85	1157	0.43	0.25	8.8
CARTER CK.										
CA-1	3	230	64.06	36.99	16.1	2.35	232	0.12	0.07	3.0
CA-2	3	111	4.36	2.52	2.3	2.04	109	0.02	0.01	0.5
MARSH CK.										
MA-1	3	76	39.20	22.63	29.8	1.84	79	0.23	0.14	7.4
MA-2	3	92	32.00	18.47	20.1	1.95	94	0.14	0.08	4.1
SADLEROCHIT R.										
SA-1	3	100	62.98	36.36	36.4	1.92	114	0.35	0.20	10.5
SA-2	3	229	53.36	30.75	13.4	2.35	230	0.11	0.06	2.6
SA-3	3	11	0.58	0.33	3.0	1.07	11	0.02	0.01	1.2
SAI-1	2	376	453.96	320.99	85.4	2.29	433	0.77	0.55	23.9
SAI-2	3	185	237.15	136.91	74.0	1.98	135	0.62	0.36	18.1

*Indicates spring areas.

Table 11. (Continued.)

Station	Sample Size	RAW DATA Mean No.	Standard Deviation	Standard Error	% Precision	TRANSFORMED DATA LOG (x+1) Mean	Derived Mean	Standard Deviation	Standard Error	% Precision
HULAHULA R.										
HH-1	3	3	2.51	1.45	48.5	0.58	4	0.27	0.16	27.1
HH-2	3	152	110.64	63.88	42.0	2.09	172	0.36	0.21	9.8
HH-3	2	25	1.41	0.99	4.0	1.41	25	0.02	0.01	1.0
HH-4	3	1	1.00	0.58	58.0	0.26	1	0.24	0.02	7.5
HH-5	3	2	1.73	0.99	49.9	0.43	2	0.23	0.13	30.2
HH-6	3	5	8.38	4.84	96.7	0.50	8	0.63	0.36	72.4
OKPILAK R.										
OK-1	3	1	1.00	0.58	58.0	0.20	1	0.35	0.20	100.0
OK-2	3	16	5.29	3.05	19.1	1.22	16	0.13	0.07	6.1
OK-3	3	2	1.15	0.66	33.2	0.20	1	0.35	0.20	100.0
OK-4	3	48	26.66	15.39	32.1	1.63	45	0.31	0.18	10.9
OK-5	3	43	9.71	5.60	13.0	1.64	44	0.09	0.05	3.3
OK-6	3	27	7.21	4.16	15.4	1.44	27	0.11	0.06	4.4
OK-7	3	1	1.73	0.99	99.0	0.20	1	0.35	0.20	100.0
JAGO R.										
JA-3	3	28	7.54	4.35	15.5	1.45	28	0.11	0.07	4.5
JA-4	3	10	15.88	9.16	91.7	0.59	6	0.77	0.45	75.6
JA-5	3	4	3.78	2.18	54.5	0.58	6	0.51	0.29	50.3
JOP-1	3	4	2.52	1.45	36.4	0.62	5	0.28	0.16	26.2
JOP-2	3	27	18.23	10.52	39.0	1.39	32	0.30	0.17	12.5
JOP-3	3	71	50.46	29.13	38.3	1.78	76	0.30	0.17	9.7
*JOK-2	3	1043	823.22	475.28	45.6	2.90	1232	0.40	0.23	8.0
ANGUN R.										
AN-1	3	40	19.30	11.14	27.9	1.56	42	0.25	0.14	9.3
NIGUANAK R.										
NI-1	3	21	2.00	1.15	5.5	1.34	21	0.04	0.02	1.7
AICHILIK R.										
AC-2	3	60	13.11	7.56	12.6	1.78	61	0.09	0.05	3.0
AC-3	3	135	36.61	21.13	15.7	2.12	131	0.13	0.07	3.4
*AC-4	2	903	922.77	652.49	72.3	2.80	1447	0.56	0.40	14.1
AC-6	3	22	13.43	7.75	35.2	1.27	26	0.37	0.21	16.8

*Indicates spring areas.

Table 12. Statistical analysis of raw data for weight of organisms/sample from all stations, 1002c Study Area, ANWR.

Station	Sample Size	Mean Wt.(gms)	Standard Deviation	Standard Error	% Precision
CANNING R.					
CN-1	3	0.233	0.128	0.074	31.7
CN-2	3	0.053	0.013	0.008	14.2
CN-3	2	0.444	0.298	0.172	38.8
*CN-4	3	1.197	0.772	0.445	37.2
TAMAYARIAK R.					
TM-1	3	0.047	0.024	0.014	29.8
TM-2	3	0.450	0.326	0.188	41.8
TM-3	3	0.197	0.242	0.140	70.9
TM-4	3	0.024	0.007	0.004	16.8
KATAKTURUK R.					
KT-1	3	0.655	0.725	0.420	63.9
KT-2	3	0.034	0.004	0.002	6.8
*KT-3	3	0.687	0.526	0.303	44.1
CARTER CK.					
CA-1	3	0.211	0.082	0.047	22.4
CA-2	3	0.262	0.110	0.006	2.4
MARSH CK.					
MA-1	3	0.089	0.054	0.031	35.0
MA-2	3	0.220	0.184	0.106	48.3
SADLEROCHIT R.					
SA-1	3	0.153	0.098	0.056	37.0
SA-2	3	0.300	0.282	0.163	54.2
SA-3	3	0.025	0.013	0.007	30.0
SAI-1	2	0.749	0.899	0.635	84.8
SAI-2	3	0.482	0.390	0.225	46.7
HULAHULA R.					
HH-1	3	0.009	0.010	0.006	64.2
HH-2	3	0.237	0.149	0.086	36.3
HH-3	2	0.048	0.006	0.004	8.8
HH-4	3	0.001	0.001	0.0005	57.7
HH-5	3	0.002	0.001	0.0006	28.9
HH-6	3	0.005	0.007	0.004	80.8

*Indicates spring areas.

Table 12. (Continued.)

Station	Sample Size	Mean Wt.(gms)	Standard Deviation	Standard Error	% Precision
OKPILAK R.					
OK-1	3	0.001	0.001	0.0005	57.7
OK-2	3	0.050	0.046		
OK-3	3	0.002	0.003	0.002	100.0
OK-4	3	0.092	0.072	0.042	45.2
OK-5	3	0.099	0.020	0.012	11.7
OK-6	3	0.058	0.047	0.027	46.8
OK-7	3	0.002	0.003	0.002	86.6
JAGO R.					
JA-3	3	0.146	0.182	0.105	71.9
JA-4	3	0.100	0.173	0.099	99.8
JA-5	3	0.003	0.002	0.001	33.3
JOP-1	3	0.005	0.003	0.002	34.6
JOP-2	3	0.054	0.045	0.026	48.1
JOP-3	3	0.127	0.138	0.079	62.2
*JOK-2	3	0.557	0.383	0.221	39.7
ANGUN R.					
AN-1	3	0.310	0.261	0.151	48.6
NIGUANAK R.					
NI-1	3	0.022	0.002	0.001	5.2
AICHILIK R.					
AC-2	3	0.079	0.014	0.008	10.2
AC-3	3	0.179	0.148	0.085	47.7
AC-4	2	0.220	0.028	0.016	7.3
AC-6	3	0.016	0.010	0.006	36.1

*Indicates spring areas.

Table 13. Mean density (no/m^2), biomass (gm/m^2), diversity (H'), evenness (J'), and number of taxa of aquatic macroinvertebrates from all stations, 1002c Study Area, ANWR.

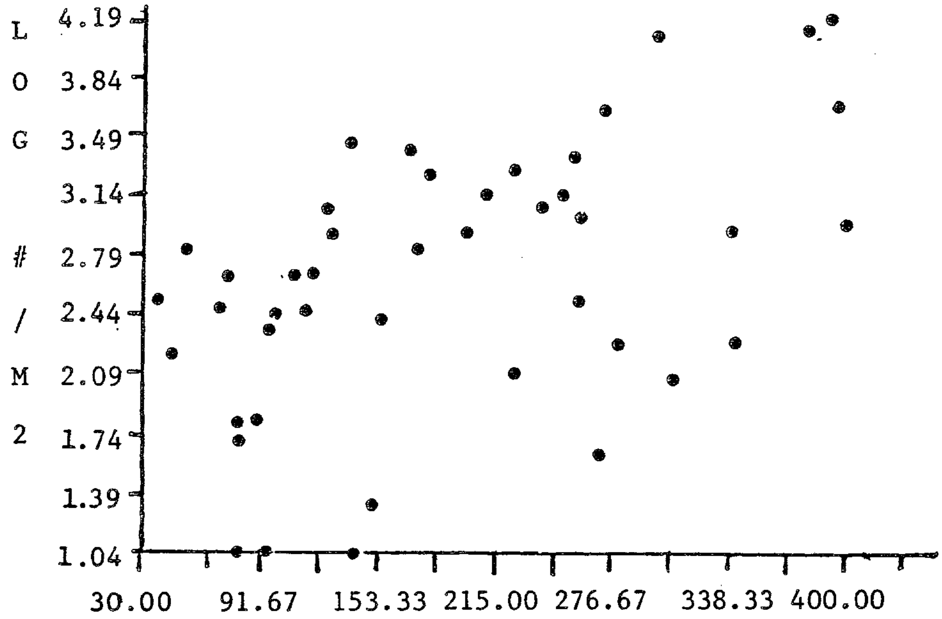
Station	Sample Size	no./m^2	gm/m^2	Diversity (H')	Evenness (J')	No. of taxa
CANNING R.						
CN-1	3	839	2.50	1.685	0.613	9
CN-2	3	667	0.57	2.479	0.853	11
CN-3	2	2752	4.77	1.301	0.470	8
*CN-4	3	11847	12.87	1.940	0.531	18
TAMAYARIAK R.						
TM-1	3	344	0.51	1.631	0.685	7
TM-2	3	1978	4.84	2.082	0.753	9
TM-3	3	1107	2.11	2.033	0.718	10
TM-4	3	129	0.26	2.001	0.902	7
KATAKTURUK R.						
KT-1	3	4300	7.04	1.423	0.522	7
KT-2	3	183	0.37	1.661	0.791	5
*KT-3	3	12406	7.39	0.863	0.339	7
CARTER CK.						
CA-1	3	2494	2.27	1.814	0.561	12
CA-2	3	1172	2.82	1.529	0.572	9
MARSH CK.						
MA-1	3	849	0.96	2.494	0.837	9
MA-2	3	1010	2.37	1.947	0.683	10
SADLEROCHIT R.						
SA-1	3	1226	8.05	1.402	0.632	5
SA-2	3	2472	3.23	1.450	0.547	7
SA-3	3	118	0.27	1.279	0.891	5
SAI-1	2	4655	8.05	1.599	0.505	11
SAI-2	3	1451	5.18	1.902	0.727	9
HULAHULA R.						
HH-1	3	43	0.10	0.417	0.263	5
HH-2	3	1849	2.55	1.765	0.619	10
HH-3	2	269	0.52	2.117	0.866	7
HH-4	3	11	0.01	0.001	0.001	2
HH-5	3	22	0.02	0.500	0.316	5
HH-6	3	194	0.05	0.501	0.317	3

*Indicates spring areas.

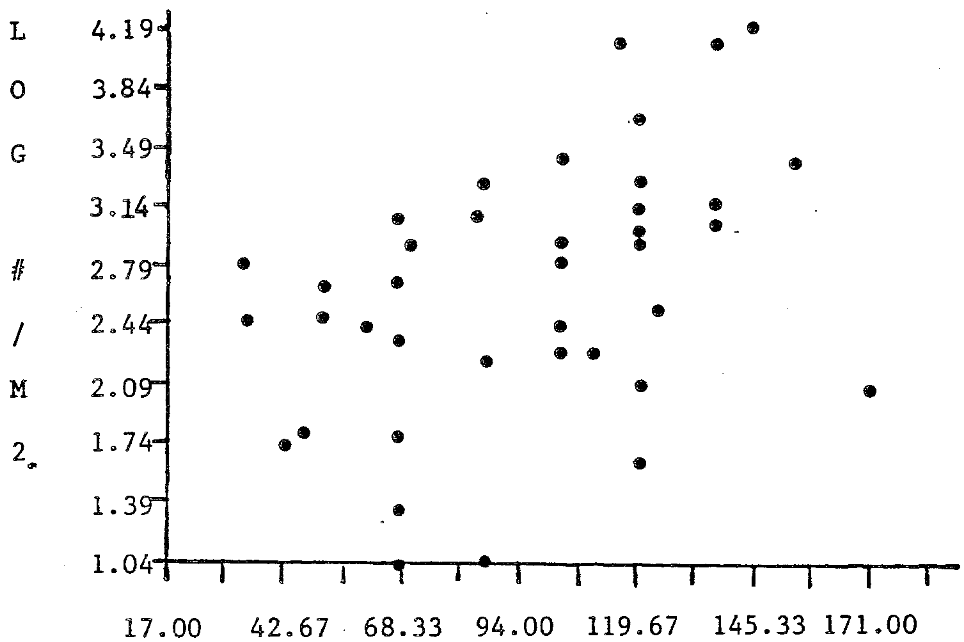
Table 13. (Continued.)

Station	Sample Size	no./m^2	gm/m^2	Diversity (H')	Evenness (J')	No. of taxa
OKPILAK R.						
OK-1	3	11	0.01	0.001	0.001	1
OK-2	3	172	0.54	1.769	0.884	6
OK-3	3	11	0.02	0.306	0.306	2
OK-4	3	484	0.99	2.085	0.783	10
OK-5	3	473	0.99	0.971	0.414	8
OK-6	3	290	0.62	2.031	0.755	11
OK-7	3	11	0.02	0.306	0.306	2
JAGO R.						
JA-3	3	301	1.57	1.608	0.664	9
JA-4	3	65	1.08	0.466	0.233	4
JA-5	3	65	0.03	0.877	0.553	4
JOP-1	3	54	0.05	0.717	0.532	3
JOP-2	3	344	0.58	2.179	0.826	10
JOP-3	3	814	1.37	1.965	0.632	14
*JOK-2	3	13244	5.98	0.600	0.247	10
ANGUN R.						
AN-1	3	452	3.33	1.611	0.734	8
NIGUANAK R.						
NI-1	3	226	0.23	0.943	0.827	9
AICHILIK R.						
AC-2	3	656	0.85	1.451	0.608	8
AC-3	3	1408	1.92	2.290	0.749	12
*AC-4	2	15555	2.37	0.019	0.019	2
AC-6	3	280	0.17	1.208	0.762	3

*Indicates spring areas.

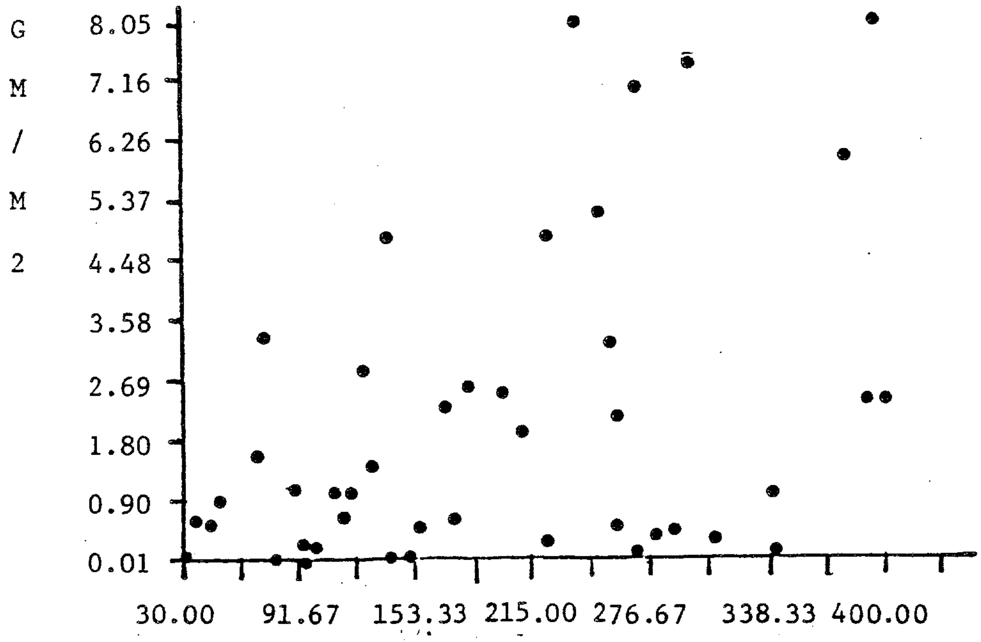


n= 45 r= +0.541 r-square= +0.293 Y = +0.0041 X +1.8516

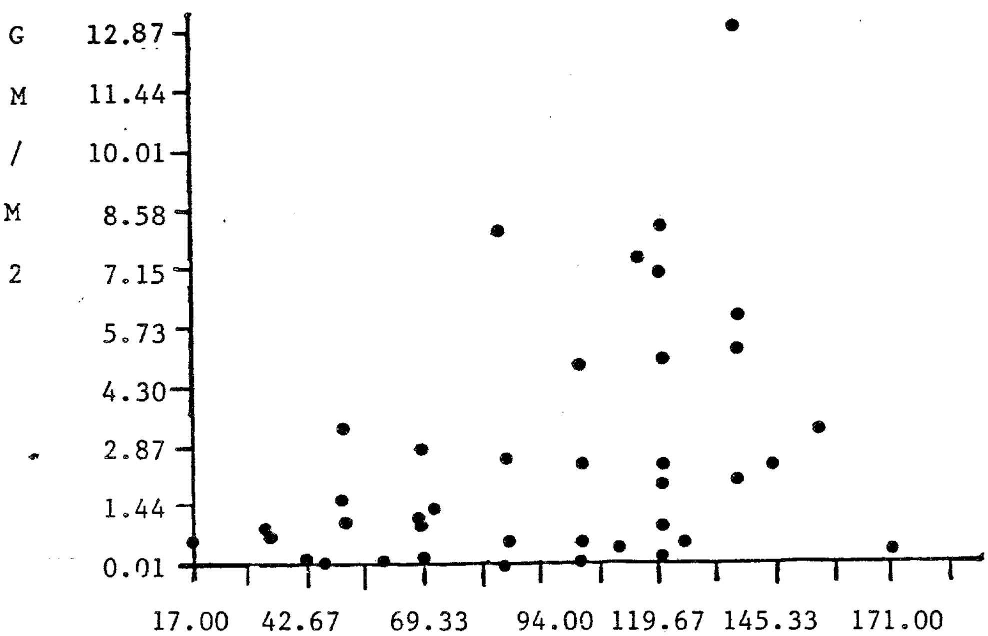


n= 46 r= +0.462 r-square= +0.213 Y = +0.0107 X +1.6543

Figure 12. Regression of alkalinity and conductivity with density (log no/m^2) of aquatic macroinvertebrates from samples collected in the vicinity of the 1002c Study Area, ANWR.

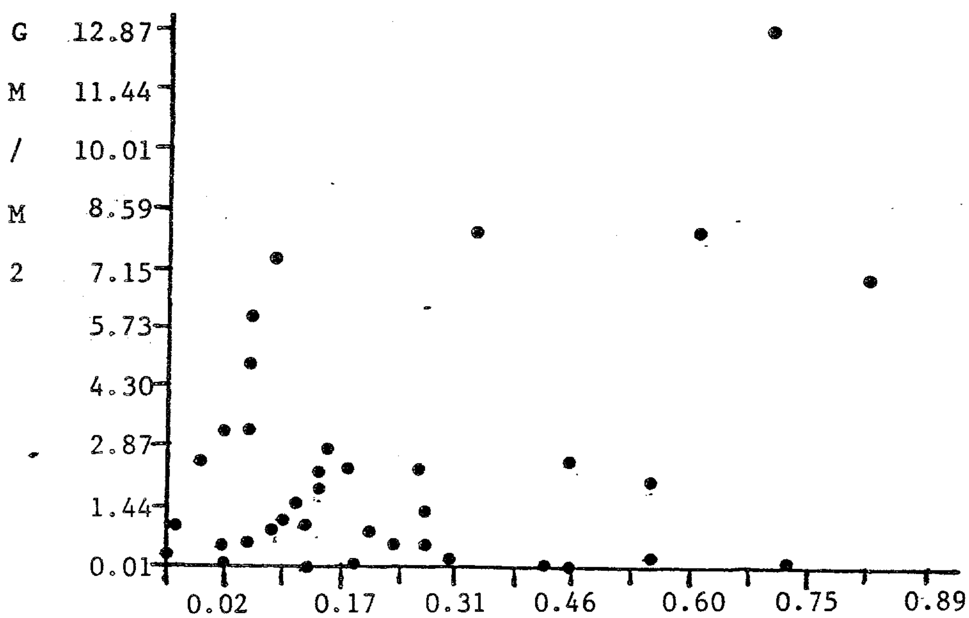


n= 45 r= +0.464 r-square= +0.215 Y = +0.0102 X +0.0814



n= 46 r= +0.395 r-square= +0.158 Y = +0.0313 X -0.0953

Figure 13. Regressions of alkalinity and conductivity with aquatic macroinvertebrates biomass (gms/m^2) from samples collected in the vicinity of the 1002c Study Area, ANWR.



n= 37 r= +0.338 r-square= +0.114 Y = +4.3289 X +1.1357

Figure 14. Regression of biomass (gms/m^2) of aquatic macroinvertebrates with average water velocity from samples collected in the vicinity of the 1002c Study Area, ANWR.